

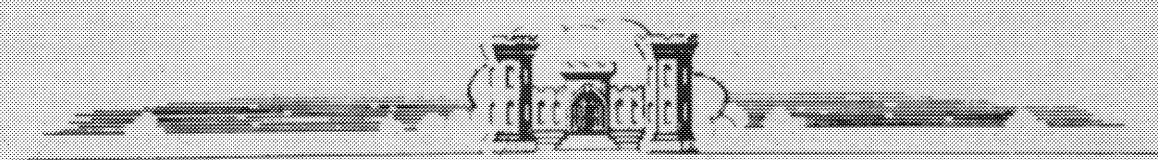
BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY

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OF CAPE COD CANAL TO PROVINCETOWN MASSACHUSETTS



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

OCTOBER 2, 1959

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF THE SHORE OF CAPE COD
BETWEEN THE CAPE COD CANAL AND RACE POINT, PROVINCETOWN, MASSACHUSETTS

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U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

NEDGW

October 2, 1959

SUBJECT: Beach Erosion Control Report on Cooperative Study of the
Shore of Cape Cod between the Cape Cod Canal and Race
Point, Provincetown, Massachusetts

TO: Chief of Engineers, Department of the Army, Washington, D. C.

SYLLABUS

This study made in cooperation with the Commonwealth of Massachusetts, includes all of the exposed coast on Cape Cod Bay between the Cape Cod Canal entrance and Race Point in the Provincelands. The purpose of the study is to determine in general the shore processes, best methods of shore protection, prevention of further erosion, improvement of beaches and specifically to develop plans for protection and improvement of Town Neck Beach, Spring Hill Beach, Brewster Bluffs area, Eastham beaches, Indian Neck, Pilgrim Beach and Provincetown State Beach.

The Division Engineer recommends that protective measures which may be undertaken by local interests based on their own determination of economic justification be accomplished generally as follows:

- a. Spring Hill Beach. - Widening about 14,000 feet of beach to a 125-foot width by placement of a stockpile of suitable sand fill at the westerly end of the beach.
- b. Brewster Bluffs. - Widen about 5,000 feet of beach to a 125-foot width by direct placement of suitable sand fill.
- c. Eastham Beaches (Private). - Widen about 8,000 feet of beach to a 125-foot width by direct placement of suitable sand fill and construction of 8 stone groins. The placement of fill to be deferred until it is determined if groins will fill naturally.
- d. Indian Neck. Construction of one groin near the center of the area.
- e. Pilgrim Beach. Construction of 8 stone groins.

The Division Engineer further recommends that the United States adopt projects authorizing Federal participation by the contribution of Federal funds in amount equal to the total cost of jetty modification

and one-third the cost of construction of the remainder of the project at Town Neck Beach, one-third the cost of construction of projects at Thumpertown Beach and Provincetown Beach and one-third the cost of periodic nourishment of Town Neck Beach for an initial period of 10 years from the year of completion of the initial work. The projects are as follows:

a. Town Neck Beach. Widen approximately 6,500 feet of beach to a 125-foot width by direct placement of suitable sand fill and raising the inshore end of the Cape Cod Canal jetty.

b. Thumpertown Beach. - Widening about 1,500 feet of beach by direct placement of suitable sand fill and construction of one stone groin.

c. Provincetown Beach. - Widening about 1,600 feet of beach by direct placement of suitable sand fill, reconstruction of 2 groins, construction of 2 new groins and construction of approximately 1,200 feet of concrete seawall.

The estimated amounts of Federal participation in the first costs of the projects are \$67,000 for Town Neck Beach, \$18,000 for Thumpertown Beach and \$93,000 for Provincetown Beach. The estimated Federal participation in the cost of the periodic nourishment is \$1,000 per year.

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF THE SHORE OF CAPE
COD BETWEEN THE CAPE COD CANAL AND RACE POINT, PROVINCETOWN, MASSACHUSETTS.

I GENERAL

1. Authority. - The study was made by the Corps of Engineers, United States Army, in cooperation with the Commonwealth of Massachusetts, (acting through the Department of Public Works, Division of Waterways), under authority of Section 2 of the River and Harbor Act approved July 3, 1930, as amended and supplemented. The formal application for the study dated June 10, 1957 was approved by the Chief of Engineers on June 19, 1957.

2. Purpose. - The purpose of the study as stated in the application, is to determine the best method of shore stabilization and protection for the north shore of Cape Cod from Cape Cod Canal, in Sandwich to Race Point in Provincetown, and to develop detailed plans for improvement of shore areas in Sandwich, Dennis, Brewster, Truro and Provincetown. After initiation of the study it became apparent from field inspections and meetings with local officials that areas in Eastham were suffering serious erosion and were therefore added for detailed study. Late in the study officials of the Town of Wellfleet asked for a plan of protection for Indian Neck in Wellfleet Harbor. Indian Neck was added for detailed study but has been treated in less detail than other principal areas.

3. Prior Reports. - There have been no prior beach erosion control reports on any of the shore area considered in this study. The Beach Erosion Control Report on Cooperative Study of the Shore between Pemberton Point and Cape Cod Canal, Massachusetts covered adjacent shore to the north.

4. Location. - The north shore Cape Cod, the study area, faces Cape Cod Bay. The opposite shore of the Cape faces the Atlantic Ocean, Nantucket Sound and Buzzards Bay. This area is in southeastern Massachusetts, about 50 to 120 miles southeasterly of Boston, and includes shore line in the Towns of Sandwich, Barnstable, Yarmouth, Dennis, Brewster, Orleans, Eastham, Wellfleet, Truro and Provincetown, all in Barnstable County. The area is shown on United States Coast and Geodetic Survey charts numbered 1208, 251, 581 and 580; on United States Geological Survey and United States Army Map Service quadrangles of Sandwich, Hyannis, Dennis, Harwich, Orleans, Wellfleet, North Truro and Provincetown, Massachusetts; and, on plates accompanying this report.

5. Population. - The United States Department of Commerce, Bureau of the Census makes a census of population each decade at the ten year date (i.e. 1940, 1950, etc.) and the Massachusetts Department of Commerce, Division of Research makes one each decade midway between the times of the Federal census (i.e. 1945, 1955, etc.). However, the figures of the two agencies are not directly comparable since the state

census excludes military personnel, students and other temporary residents. Table 1 lists the Federal census for 1940 and 1950 and the State census for 1945 and 1955.

TABLE 1

<u>Town</u>	<u>Length of Shore in Miles</u>	<u>Population</u>		<u>Percent Change</u>	<u>Population</u>		<u>Percent Change</u>
		<u>1940</u>	<u>1950</u>		<u>1945</u>	<u>1955</u>	
Sandwich	6.3	1,360	2,418	78	1,524	1,642	8
Barnstable	6.3	8,333	10,480	26	8,647	12,051	39
Yarmouth	7.2	2,286	3,297	44	2,461	4,156	69
Dennis	7.3	2,015	2,499	24	1,807	3,322	46
Brewster	6.3	827	987	19	757	1,172	55
Orleans	1.2	1,451	1,759	21	1,543	2,201	43
Eastham	5.7	582	860	48	604	1,107	83
Wellfleet	20.7	890	1,123	26	851	1,331	56
Truro	8.7	585	661	13	582	851	46
Provincetown	9.7	3,668	3,795	3	3,546	3,415	-4
Total	73.4	21,997	27,879	26.7(1)	22,322	31,248	40(1)

(1) Average change for entire area considered.

However this permanent population recorded by the census is principally the owners and/or operators of facilities for the summer and transient residents who are the largest users of the beaches and shore. It is estimated that the Cape Cod population during the summer months is at least 3 times that of the permanent population. It is evident from the census figures that the permanent population of Cape Cod is growing, and presumably the summer population is increasing by a similar percentage. The summer population of Cape Cod is, in fact, not entirely dependent upon permanent population nor on population of adjacent cities and towns, as it draws from throughout the United States and Canada.

6. Description. - The study area is a glacial deposit and shore line of submergence. The shore is generally sandy with intermittent areas where strata of clay are visible in wave cut bluffs. The westerly four miles, from Cape Cod Canal to Scorton Harbor, there is narrow sandy beach with low dunes along the backshore and the beach is interrupted by two inlets, Sandwich Harbor and Scorton Harbor. There is considerable number of summer cottages along this reach of shore. From Scorton Harbor to Beach Point the shore composes a sand neck, with high dunes throughout. This area is relatively undeveloped and forms the northerly protection for Barnstable Harbor. From Barnstable Harbor easterly to the Brewster-Orleans town line there are rather narrow sand beaches with small dunes along the back of the beach except for head-



Fig. 1 Cape Cod Canal Entrance, Sandwich. 7 April 1959 -
Looking east along jetty. Note flow over jetty
into canal.



Fig. 2 Town Neck Beach, Sandwich. 7 April 1959 - Looking
southeasterly along beach from Cape Cod Canal jetty.



Fig. 3 Spring Hill Beach, Sandwich. 13 May 1958 - Easter-
ly along beach from a point east of Sandwich Harbor.

lands up to 50 feet high just west of Sesuit Harbor and east of Quivett Creek. From the Orleans town line to about First Encounter Beach in Eastham, the shore is flat sandymarsh with inlets for Namskaket Creek, Little Namskaket Creek, Rock Creek, Boatmeadow River and Herring River. From First Encounter Beach to Wellfleet Harbor there are sandy bluffs with beaches along the toe of the bluffs. There is a rather severe erosion area in the vicinity of the highest bluffs. Wellfleet Harbor is low and marshy along the southerly portion then lined by high sand banks from about Lieutenant Island along its northerly and easterly banks. The area from Jeremy Point to Pamet River is a tombolo system made up of about two miles of high bluff of Truro mainland at the north end, the group of Bound Brook Island, Griffin Island, Great Island and Great Beach Hill which are tied together, and a spit about a mile long extending from Great Beach Hill to Jeremy Point. This system forms the westerly protection for Wellfleet Harbor. From Pamet River northward to Pilgrim Beach there are sand beaches fronting bluffs generally about 50 feet high, except for Harbor Bar which extends from the north jetty at Pamet River to Corn Hill about 4,000 feet northward. Pilgrim Beach is a low, narrow barrier between Pilgrim Lake and Provincetown Harbor and is lined with motels and rental cottages. From this point westward along the shore of Provincetown the backshore is generally about 20 feet above mean low water. The southerly end is lined with dwellings followed by harbor facilities and commercial properties. Long Point to the west, part of the Provincelands State reservation, is an undeveloped spit, covered by high dunes, which curves southward, then eastward and then northward.

7. The shore throughout the study area is rather sparsely developed except at summer communities spaced throughout and at Pilgrim Beach and the City of Provincetown. Groins are the principal type of protective structure found in the area, although short reaches of seawall and revetment may also be found. More detailed information regarding description of the area and the structures along the shore may be found in Appendices A and D and on Plates accompanying this report.

8. The shore is principally privately owned, however, scattered throughout are areas owned by the Federal Government, the Commonwealth and the various towns. A listing of the principal areas in public ownership are given in Table 2 and shown on Plates 2 to 10. In general the towns have obtained street ends and adjacent frontage (known as town landings) at intervals along the shore and have constructed small paved parking areas. In many instances where such accessibility has been established people not only use the publicly owned frontage but spread beyond for significant distances. In most instances greater use of these small public beaches would be obtained by enlarging the parking areas.

TABLE 2

Principal Publicly Owned Shore

<u>Town</u>	<u>Beach</u>	<u>Shore Frontage in Feet</u>	<u>Facilities</u>
Sandwich	Town Beach	5,500	2 Parking areas, small bathhouse.
	Spring Hill Beach	275	
	Spring Hill Beach	100	
Barnstable	Sandy Neck	12,430	Paved parking area, picnic tables, snack bar, trash receptacles near Sandwich - Barnstable town line.
	Beach Point (Fed.)	680	
Dennis	Comfort Rd-Bass Hole	6,100	Paved Parking areas (150 cars) Bathhouse & paved parking
	Taunton Ave.	125	
	Horsefoot Path	400	
	Bayview Road	675	
	Nobscusset Pt.	900	
	West of Sesuit Hbr.	275	
	East of Sesuit Hbr.	2,500	
Brewster	Paines Creed Rd.	1,800	Paved parking area
	Robbins Hill Rd.	112	
	Breakwater Idg.	330	Paved parking area
	Points of Rocks Idg.	50	Paved parking area
	Ellis Idg.	50	Paved parking area
	Linnells Idg.	60	Paved parking area
	Crosby Lane	225	Paved parking area
Orleans	Skaket Beach	1,100	Paved parking area
	Rock Harbor	280	Paved parking area
Eastham	Rock Harbor Beach	500	Pave parking area (90 cars)
	Beach Meadow Beach	530	
	First Encounter Beach	3,000	
	Memorial Park Beach	150	
	(State)		
	Cole Road	160	Paved Parking Area
	Kingsbury Beach	36	
	Thumpertown Idg	1,023*	
	Campground Idg	200	
	Cocks Brock Rd.	200	
	Sunken Meadow, South	150	Paved parking area (75 cars)
	Sunken Meadow, North	100	Paved parking area

<u>Town</u>	<u>Beach</u>	<u>Shore Frontage In Feet</u>	<u>Facilities</u>
Wellfleet	Indian Neck (Wellfleet Hbr.) southward to Pilgrim Rd.	2,500	Unpaved parking area.
	Indian Neck, south from jetty	200	Parking area under construction
	Chequesset Rd. northward	700	Paved parking area (200 cars)
	Griffin Rd. northward	1,200	Paved parking area (200 cars)
Truro	Ryder Beach	250	Parking area (200 x 200 ft.)
	End of Fisher Rd.	40	
	South from Corn Hill Road	3,100	Paved parking area (400 x 400 ft.)
	Great Hollow Rd. end	250	Paved parking area (80 x 325 ft.)
	Beach Pt.	40	Paved parking area (100 x 200 ft.)
Province-town	Old High Head Rd.	240	
Province-town	Provincetown Beach	25,000	Extensive paved
	(Provincelands Res. State)	(4,000 developed for bathing use)	parking areas

* The Town of Eastham has instituted proceedings to obtain an additional 500 feet of adjacent frontage.

9. Statement of the Problem. - The problem is basically one of general erosion due principally to the paucity of littoral drift below natural barriers and to accelerating erection of protective structures which eliminate sources of supply of the material which formerly provided equilibrium under natural shore processes. Part of the problem is also to eliminate the natural erosion of bluffs, which have long been eroding and furnishing sand to the downdrift beaches, to encourage or protect future or existing development thereon. Since Cape Cod is a resort area local interests are concerned with the permanence of their beaches and the maintaining of a natural appearance in the areas.

10. No general public hearings were held but close liason was maintained with the Division of Waterways of the Massachusetts Department of Public Works, the cooperating agency. Meetings were also held with officials and representatives of the various towns involved. During preparation of the report a meeting was held with the Barnstable County Selectmen's Association wherein the purpose and status of the study was discussed and the comments and suggestions of the Selectment of the affected towns were considered. Upon completion of the development of detailed plans for protection of problem areas meetings were again held with state and town officials to obtain their views on the plans.

PART II FACTORS PERTINENT TO THE PROBLEM

11. Geomorphology. - The existence of Cape Cod, the Massachusetts Islands, Block Island and Long Island results from a ridge, or "Cuesta", of rocks of Cretaceous age, generally regarded as the New England extension of a wider coastal plain occurring to the south. This serrated ridge, which borders the coast, has served as a barricade for glacial sediments which were plowed and washed from the hard rock mainland towards the sea to form islands and the Cape Cod peninsula.

12. Two major glacial morainic ridges, composed of material dumped by the glacier, are prominent in southern New England. One, the Ronkonkoma moraine, makes up the southern half of Long Island, submerges and reappears at intervals as the "spines" of Block Island, Martha's Vineyard and Nantucket. The other, the Harbor Hill moraine, occurs as a long ridge, making up the northern half of Long Island. It crosses under Long Island Sound, emerges as the seaward extension of Watch Hill, Rhode Island, crosses southern Rhode Island to Narragansett Bay and reappears as the Elizabeth Islands, forming the southeastern margin of Buzzards Bay and the northern part, or "backbone" of Cape Cod as far eastward as Orleans. This Cape Cod portion of the Harbor Hill moraine is called the Falmouth moraine and is divided into two lesser features known as the Buzzards Bay moraine and the Sandwich moraine. They are generally regarded as marking the front of two distinct lobes of the same glacier. The two moraines intersect and terminate just west of the center of the Cape Cod Canal. The Buzzards Bay moraine runs southward to form the east headland of Buzzards Bay, while the Sandwich moraine extends along the upper edge of the "arm" of the cape to Orleans. The two ridges form an approximate right angle, and the inclosed area of the southeast quadrant is composed predominantly of glacial outwash in the form of a layered slightly convex plain, which slopes eastward. It is referred to as a "pitted" plain because of numerous depressions, called "kettles", formed by the melting of buried ice blocks. The forearm of the cape is composed of ground moraine and outwash material extending as far north as Truro and, beyond Truro, a complex series of sand spits making up the Provincelands, or "hand" and "wrist".

13. It is the considered opinion of at least one authority (Johnson), that "No marked change has occurred in the Cape Cod region during the last few thousand years". This does not mean that the area is inactive. The cape is a youthful and ephemeral feature, and processes which tend to flatten it landward are constantly at work. Evidence that drift currents and waves are still pushing these materials exists in the form of submarine ridges northeast of Race Point, which are easily distinguished on the sounding chart. This pushing is a broad effect and is not inconsistent with the idea of opposing drift currents

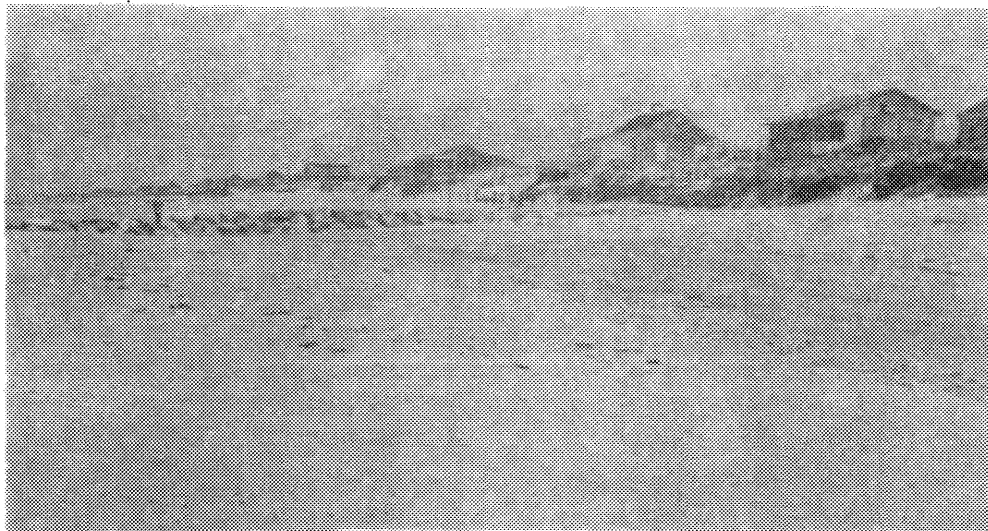


Fig. 4 Spring Hill Beach, Sandwich. 13 May 1958 - Easterly toward east end of beach.



Fig. 5 Sandy Neck Beach, Barnstable. August 1958 - At developed public beach area looking easterly toward outer end of Sandy Neck.



Fig. 6 Brewster Bluffs Area, Brewster. 12 August 1958 - From vicinity of Point of Rocks looking easterly toward detailed study area.

which can and do move materials southward as at Chatham Bar on the outer "elbow". Evidences of earlier locations of the northern outermost tip of the cape are seen in the form of old beach ridges and cliffs in Truro. Eventually the supply of glacial materials for building outward will be depleted. The diminution of the supply of drift materials combined with the pushing of materials farther to sea and into Massachusetts Bay will result inevitably in a major breaching of Cape Cod in the Truro area in the next few thousand years. Most of the more spectacular erosional effects are to be observed along the outer "fore-arm" rather than the area involved in this study, the bay side being characterized mostly by smaller wave-built forms. Major features do exist, however, notably the complex Provincetown spit, Wellfleet Harbor with its elaborate tombolo formations, Sandy Neck spit with its old beach ridges, and Barnstable Harbor where the ice contact side of the Sandwich moraine shows concave scallops and larger embayments are enclosed by baymouth bars. A smaller morainic feature, the Scorton moraine, lies north of the Sandwich moraine between the canal and Barnstable Harbor. Its effect is to leave cobbles, large boulders, and occasional clayey deposits on the beach. Somewhat similar materials are quarried from thin ground moraine deposits overlying clay beds which extend along the coast from Barnstable Harbor to Orleans. In summary, post-glacial changes on Cape Cod have been limited to rapid marine erosion, extensive wind erosion and the formation of dune belts, minor stream erosion, and the growth of swamps and marshes.

14. Littoral Materials. - Littoral materials along the Cape Cod Bay shore of Cape Cod between Cape Cod Canal and Eastham consists generally of fine to medium sand. North from Eastham the sand is generally in the medium range with a small amount of coarse sand and some coverage of gravel between mean high and mean low water. Information on analysis of surface sand samples taken at various locations are tabulated in Appendix A.

15. Erosion of the beaches and of the high sandy banks and dunes supplies littoral drift along the area. Artificial sources of material for the shore are available in inland dunes and in offshore bars.

16. Littoral Forces. - a. Waves. The south shore of Cape Cod Bay is exposed to waves from the north and north-northeast with the fetch limited by the coast of Maine, a distance of about 150 miles. The south and east shores of Cape Cod Bay are exposed to waves generated in Cape Cod and Massachusetts Bays from the west to north-northwest, with maximum fetch of about 65 miles. The south shore of Cape Cod Bay is also exposed to waves from the northeast generated within the bay with a maximum fetch of about 30 miles. Considering these fetches and usual storms in this area deepwater waves of about 20, 16 and 12 feet could be expected. However, for shore protection structures the depth of water occurring at the structure is usually the critical factor in determining effective wave heights. For general information Table B-6 and the wave rose on Plate 1 shows deepwater wave data for a station off Nauset Beach.

b. Winds. - Prevailing winds are from westerly directions and act over limited fetches as described in paragraph 16a. The wind rose on Plate 1 shows distribution, duration and average speed of winds observed by the U.S. Weather Bureau at Logan International Airport in Boston during the period October 1949 through September 1958.

c. Storms. - The frequent and severe northeast storms are considered most damaging to the shores in New England. In the study area the north shore of Cape Cod, west of Barnstable Harbor are the most severely effected by these storms. The remainder of the study area is more seriously affected by westerly and southwesterly storms. The storm wind diagram circumscribing the wind rose on Plate 1 shows distribution of winds over 32 miles per hour which have occurred at Boston.

d. Tides. - Mean and spring tide range in the study area range from 8.7 and 10.1 feet, respectively, at Cape Cod Canal entrance to 10.0 and 11.6 feet, respectively, at Wellfleet Harbor. Mean and spring range at Boston Harbor are 9.5 and 11.0 feet, respectively. Mean tide elevations throughout the area are considered directly proportional to that at Boston Harbor. Analysis of 30.3 years of records of tide in Boston Harbor were made for this study. The highest tide occurring was 13.8 feet and the maximum height which occurs on an average of once each year is 3.1 feet above mean high water or 12.6 feet above mean low water. Additional information on tides may be found in Appendix B.

17. Shore History. - History of the shoreline and offshore changes is obtained generally from several surveys made between 1859 and 1955 by the United States Coast and Geodetic Survey. The same surveys do not cover the entire area of study. Detailed information on changes is given in Appendix E. The general trend of change in the high water shoreline is recession although at localized areas accretion has occurred. The recession in general has averaged between 1 and 4 feet per year. Greater rates of erosion have occurred in low migrating areas such as at the mouths of Quivett and Namskaket Creeks. The higher rates of accretion have occurred in the lengthening of Beach Point, Jeremy Point and Long Point and in the filling of the old outlet to Pilgrim Lake after it was dammed.

18. Prior Corrective Action and Existing Structures. - The most widely used corrective measure of the area is the groin. The groins are generally constructed of stone although some light timber pile and sheeting groins have been used. There are, of course, a small amount of concrete and masonry seawall, stone revetment and sand fill. Detailed information on existing structures is given in Appendix D and photographs of typical structures are shown herein.

19. The groins in most cases have been effective in slowing or eliminating erosion within the groin field or to the updrift of a single groin. However, in many cases the downdrift area has suffered as a result. At some locations such as at Town Neck Beach and Spring Hill Beach in Sandwich groins have slowed the rate of loss but there is insufficient drift to allow fully effective action of groins unless sand fill is added. Jetties constructed for navigation purposes, but which affect shore processes are located at Cape Cod Canal, Sandwich Harbor, Scorton Harbor, Sesuit Harbor and Pamet River. The jetties are constructed of stone and have developed sand fillets on the west and south sides. Little or no sand has accumulated on the east or north sides. Additional information on structures is presented in Appendix D and indication of littoral transport at jetties and groins is presented in Appendix C.

20. Profiles. - Field survey work for this study, made in July - November 1958, was limited to the six areas considered in detail. In these six areas 40 profiles and 95 surface sand samples were taken (see Plates 21 and 22 and Appendix A). There were 9 profiles made at Town Neck Beach in Sandwich, 6 at Spring Hill Beach in Sandwich, 4 east of Sesuit Harbor in Dennis, 3 in Brewster, 3 in Eastham, 12 in Truro and 3 at Provincetown Beach. Average berm elevations expressed in feet above mean low water and foreshore slopes are as follows:

<u>Area</u>	<u>Average Berm Elevations</u>		<u>General Range of Slope</u>
	<u>Above MLW</u>	<u>Above MHW</u>	
Sandwich	13	4.5	1 on 9 to 1 on 20
Dennis	14	4.5	1 on 9 to 1 on 20
Brewster	14	4.5	1 on 13 to 1 on 20
Eastham	14	4.0	1 on 11 to 1 on 13
Truro	13.5	4.0	1 on 8 to 1 on 10
Provincetown	13	4.0	1 on 9 to 1 on 11

21. Volumetric Accretion and Erosion. - Most of the shoreline in the study area is eroding. The rate of change actually ranges from areas of accretion to extreme erosion. However, most of the shore appears to be retreating at an average rate ranging from 1 to 4 feet per year. Specific areas have been changing as follows:

a. Town Beach in Sandwich, about 6,500 feet in length, has retreated an average of 3 feet per year or has lost about 8,000 cubic yards per year.

b. Spring Hill Beach in Sandwich, about 6,000 feet of the northwesterly end has retreated an average of 2 feet per year or lost about 6,000 cubic yards per year, the remaining 8,000 feet of shore has moved back and forth with generally little overall change.

c. Beach Point at the outer end of Sandy Neck, in Barnstable has grown in length an average of 5.7 feet per year or has gained about 10,000 cubic yards per year.

d. In Eastham from Silver Springs road to Campground Landing about 6,000 feet, the shore has retreated about 1 foot per year or lost about 7,500 cubic yards per year. Between Campground Landing and Kingsbury Beach, about 7,000 feet, the shore has retreated about 1 foot per year a loss of about 8,500 cubic yards per year.

e. At Indian Neck in Wellfleet Harbor about 4,000 feet of shore, between the jetty and the creek near the center of the neck, has retreated an average of 1 foot per year or loss of 2,000 cubic yards per year.

f. At Pilgrim Beach in Truro, 12,000 feet of shore has retreated an average of 1.5 feet per year or lost about 12,000 cubic yards per year. At the closed entrance to Pilgrim Lake, the shore has moved seaward gaining about 10,000 cubic yards per year.

III ANALYSIS OF THE PROBLEM

22. General. - Wave action is the principal cause of damage in the study area, both for loss of beach material and damage to structures. There is sand or sand and gravel beach throughout the area with back-shore ranging from very high dunes or bluffs, principally of sand, to low marsh areas. The beach alignment, due to the hook at the outer end of the cape, changes 360 degrees. The rather limited amount of protective works in general permits a flow of material between natural littoral obstructions. Despite this natural flow there is in general a paucity of littoral drift. The recent trend of construction of works to retain the sand and eliminate loss of dunes will cause a greater and greater paucity in drift and therefore more rapid erosion of unprotected areas. Since Cape Cod is predominantly a resort area and depends on good beaches it is necessary that due consideration be given to the effect of any protective works on these beaches. Large quantities of sand are being removed for commercial purposes from the Town of Truro and possibly other parts of the cape. This practice is detrimental to the retention of the natural appearance of the Cape and will result in a loss of supply of sand for protection of beaches as well as hasten possible breaching of the Cape. This problem should be considered by the State and local governments. Briefly summarized, the characteristics of the several sections are as follows:

a. Cape Cod Canal to Barnstable Harbor. From the canal to Scorton Harbor the shore is relatively low and is eroding. There are 25 groins in this reach, in good to fair condition. Local interests plan to repair the structures during 1959. There is a deficiency in littoral drift which flows predominantly in a west to east direction. The jetty at the Cape Cod Canal is too low to act as a complete barrier to the littoral drift during reversals when the drift flows from the east. Sand flows over the jetty into the canal forming a bar adjacent to the structure. To reduce losses the jetty should be raised between the shore end and the mean low water line on the beach.



Fig. 7 Thumpertown Beach, Eastham. 13 August 1958 - Looking northerly along public beach area.



Fig. 8 Campground Landing Beach, Eastham. 13 August 1958 - Looking northerly along public beach area.



Fig. 9 Silver Spring Beach, Eastham. 13 August 1958 - Looking northerly along public beach area.

In addition to the jetty modification, direct placement of sand fill appears to be the most suitable method of protection for Town Neck Beach. East from Scorton Harbor the shore, which is very sparsely developed, is low with dunes becoming larger to the east. On Sandy Neck there are very high dunes. Placement of a stock pile of sand along the westerly end of Spring Hill Beach and of Sandy Neck would enrich the littoral drift thereby reducing erosion.

b. Barnstable Harbor to Wellfleet Harbor. - Except for the low marsh area in Orleans and in the vicinity of Herring River in Eastham, the shore consists generally of narrow beaches fronting bluffs ranging to 50 feet in height. Dredging and spoiling material on the east of Sesuit Harbor in Dennis by the Commonwealth has eliminated that problem. However since replenishment will be needed in the future it is suggested that spoil from future dredging also be placed on this beach. West of the center of Brewster the predominant direction of drift appears to be from east to west then changing to east then north through the remainder of the area. There appears to be sufficient littoral drift to fill groins but the construction of a number of groins at one time without fill would probably damage adjacent areas. Therefore, use of artificial sand fill or construction of a limited number of groins each year should be the principal method of protection. The Cape Cod Bay beaches in Orleans are flat, low and covered by beach grasses. To make an area suitable for bathing it is necessary to strip the grass and thereby make the area vulnerable to erosion forces. Therefore to minimize erosion, when enlarging the public beach is required, the area to be stripped should be limited to actual area needed. Erosion is also occurring within Wellfleet Harbor. Indications of this erosion are visible along Lieutenant Island, Indian Neck and along the inside of the glacial till islands of the tombolo system protecting the harbor from the west. Sand fill or construction of low groins would also be the most effective method of protecting this area.

c. Wellfleet Harbor to Pilgrim Beach. - The area between Pamet River and Jeremy Point is a system of high, sandy glacial till islands tied together by rather low connecting beaches. North of Pamet River there are narrow sand beaches fronting sandy bluffs generally 50 to 100 feet high. While the Pamet River entrance is at the south end of Harbor Bar, the spit was probably formed by northward littoral drift with later breaching at the present location. The fillet south of south jetty demonstrates the predominance of drift to the north. The few groins existing in the area appear to have been effective. Placement of artificial sand fill and possible use of groins to retain the fill in vulnerable areas appears to be the most suitable plan of protection for this area. Any dredging at Pamet River for navigation or other purposes should be placed on the north side to help maintain Harbor Bar.

d. Pilgrim Beach. - Pilgrim Beach is a narrow barrier between Pilgrim Lake and Cape Cod Bay. A state highway runs the length of the barrier. Seaward of the highway the shore is very highly developed with motels and rental cottages. Except at the northwest end the beach is very narrow and is lined by a seawall and several groins. Despite the protective works the beach is too narrow and low for protection from intense storms and hurricane tides. The predominant direction of littoral drift is southeast to northwest. The old entrance to Pilgrim Lake (now dammed) has been shoaling at a rate of about 10,000 cubic yards per year. It appears that since there is adequate material in movement the beach to the southeast of the entrance could be protected by a system of groins. The groins should be constructed beginning at the northerly end and progressing southerly.

e. Provincetown Harbor. - The harbor area is lined by stone revetments and walls which adequately protect the shore. There appears no need for further protection at this time.

f. Long Point, Provincelands. - The root of Long Point is a marsh area with a barrier beach along its ocean side. The remainder is a high, duned spit extending south then east. A dike extends from high ground at Provincetown across the marsh to the dunes near the outer end to prevent breaching of this arm which is the protection for Provincetown Harbor. Inside the arm the predominant direction of drift is apparently toward the point according to spit formations near the outer end. Along the outside of the arm waves resulting from the predominant northerly winds cause general movement toward the outer end as indicated by the continuous growth of the point. A stock pile of sand near the root would appear to be the best method of preventing erosion along this area.

g. Provincetown (new) Beach. - This is a State beach located immediately northwest of the root of Long Point. The predominant direction of drift is northwest to southeast. In the past this beach eroded back to the point that the state highway behind was in critical danger of damage. However, in late winter and early spring of 1958 the series of severe northeast storms rebuilt the beach to some extent. By spring of 1959 the southerly end of the beach had again narrowed to the degree that damage was occurring to the paved surface fronting the bathhouse. The area is subject to rapid changes in beach profile. A suitable plan of protection would be a system of 4 substantial groins together with sand fill forming a beach at least 125 feet wide and a seawall to prevent loss of pavement and possibly the bathhouse during severe storms.

23. Design Criteria. - Proposed protective measures are designed to provide protection against ordinary storm conditions of comparatively frequent occurrence (at least once each year). They are not intended to provide complete protection to waterfront structures in event of a hurricane or exceptional storms of infrequent occurrence, although even under these conditions some protection will be afforded.



Fig. 10 Indian Neck, Wellfleet. 13 August 1958 - Looking southerly along beach from area of public access.

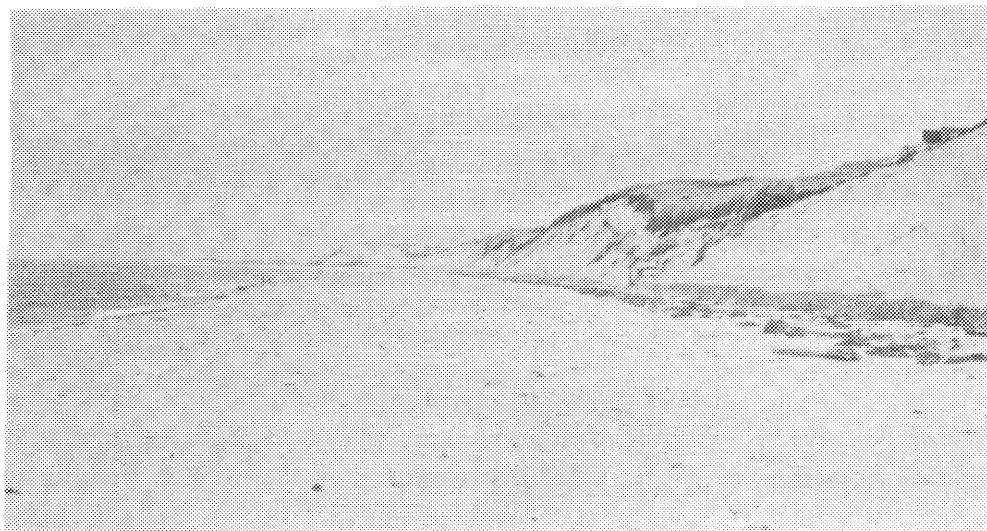


Fig. 11 Griffin Island, Wellfleet. 19 August 1958 - Looking north along public beach at Chequesset Neck Road



Fig. 12 Pilgrim Beach, Truro. 20 August 1958 - Looking northerly along motel area from public landing.

a. Design Tide. - The design tide is the maximum elevation which occurs at least once each year. Tide records at Boston indicate that stages in excess of 3 feet above the plane of mean high water occur about once each year.

b. Groins. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of berms of existing beaches and a length equal to the width of the anticipated beach. As indicated in paragraph 20, berm elevations in this area generally average about 4 to 5 feet above mean high water, therefore the top elevation should also be 4 to 5 feet above the plane of mean high water. Barrier groins which are intended to completely block passage of littoral drift or to reduce it considerably should be higher than the anticipated beach berm. The intermediate sloped section should not be steeper than the slope of the existing foreshore, and should approximately equal the anticipated beach slope. The top elevation of the outer section should not be lower than 1 foot above the plan of mean low water. For stone construction, the minimum height of groins should be determined by the size of stone needed to resist movement by wave action. Groins should be sand tight and firmly anchored at their shore ends to prevent flanking. Groin lengths are generally determined by the shape of the fillet and required width at the updrift end of the space between groins. Stone sizes and side slopes for groins are computed using the Iribarren method as described in Technical Report No. 4 of the Beach Erosion Board entitled "Shore Protection and Planning and Design." The design wave used is the maximum wave than can approach the structure, without breaking, in the depth of water at the groin if the fetch is not a limiting factor. Throughout the study area, such maximum waves can be generated with the available fetch. Blankets of spalls or crushed stone are used under stone groins or jetties to minimize settlement due to scour.

c. Sand Fills. - Berm elevations of proposed fills are based on those of existing beach berms. The minimum width of fills is based on widths found to afford protection in the area. Computed volumes of fills are based on slopes similar to existing slopes but fills can be placed initially to a steeper slope and permitted to take a natural slope under wave action. Based on these criteria berm elevations are approximately 4 to 5 feet above mean high water and beach widths above mean high water are approximately 125 feet with fill slopes of 1 on 20 to 1 on 30. Suitable sand for beach fills would have size and gradation characteristics similar to those of the sand components of the existing material on beaches. In this area the average annual recession is about 1 to 4 feet. The replenishment of beach sand will vary for each area depending upon the overage rate of erosion and the length of beach to be protected. For the purpose of detailed design of beach fills, the investigations of materials on the beaches and in proposed borrow areas given in this report should be supplemented prior to preparation of plans and specifications.

IV. PLANS OF IMPROVEMENT

24. General. - The formal application for this study requested general study of the entire shore within the limits of the study area and detailed study of specific problem areas at Town Neck Beach, Spring Hill Beach, East of Sesuit Harbor, Brewster Bluffs, Griffin Island, Pilgrim Beach and Provincetown State Beach. Before initiation of the study the cooperating agency requested that the Griffin Island area be omitted, and in connection with a dredging project at Sesuit Harbor placed sand on the beach, east of the harbor, thereby remedying a large portion of that problem. During the course of study, problems meriting additional study were discovered at Eastham and at Indian Neck in Wellfleet Harbor. These two sites were included in the areas of detailed study although a field survey was not made at Indian Neck. Discussions of plans for the areas of detailed study is in following paragraphs and the areas are shown on maps accompanying this report.

25. Town Neck Beach, Sandwich. - Details of this plan are shown on Plate 23. This beach which is about 6,500 feet long can be protected by raising the inshore end of the Cape Cod Canal jetty by placing about 1,400 tons of stone and widening the beach to 125 feet by direct placement of 165,000 cubic yards of sand on the beach. The beach will require replenishment at suitable intervals, to be determined by experience, at an estimated annual rate of about 4,000 cubic yards.

26. Spring Hill Beach, Sandwich. - Details of this plan are shown on Plate 23. The larger amount of erosion of this beach, about 14,000 feet long, has occurred along the westerly half. However, in recent years, damage has accelerated in the easterly half. The most feasible plan for protection of this area is to place about 266,000 cubic yards of sand in a stock pile about 2,500 feet long near the westerly end. The sand would be moved easterly by natural forces. The stock pile should be replenished at suitable intervals, as determined by experience, at an estimated average rate of about 5,000 cubic yards per year.

27. East of Sesuit Harbor, Dennis. - The problem at the publicly-owned frontage, adjacent to Sesuit Harbor east jetty and where the greatest erosion has occurred, was corrected by the Commonwealth of Massachusetts in 1958 when spoil from dredging the harbor was placed on the beach. Movement of this material is now widening the beach fronting the private property consisting of about 2,000 feet of frontage east of the filled area. To maintain this fill it is suggested that spoil from future dredging of Sesuit Harbor be placed on this east shore.



Fig. 13 Pilgrim Beach, Truro. 20 August 1958 - Looking southerly along beach from a point near north end.

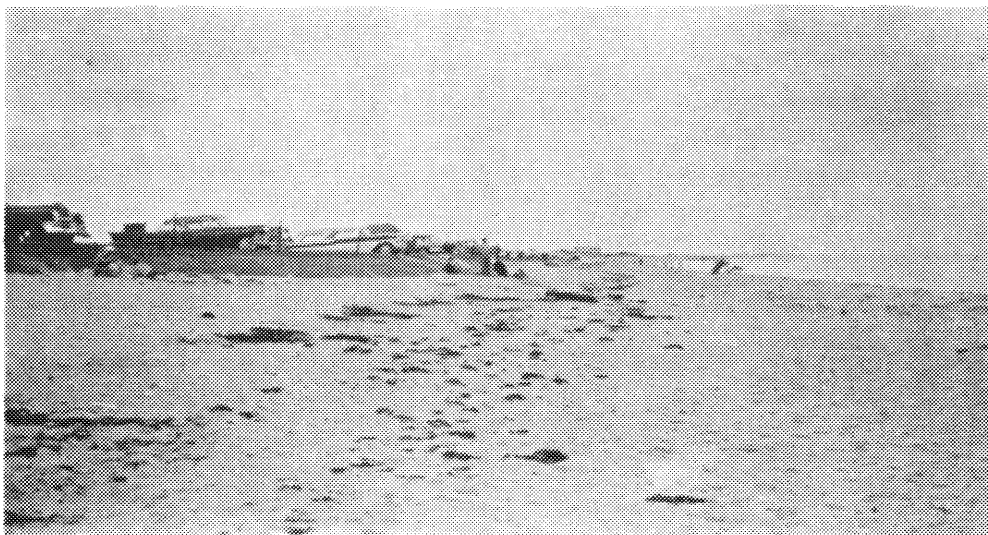


Fig. 14 Provincetown (new) Beach, Provincetown. 28 August 1958 - Looking south along beach.

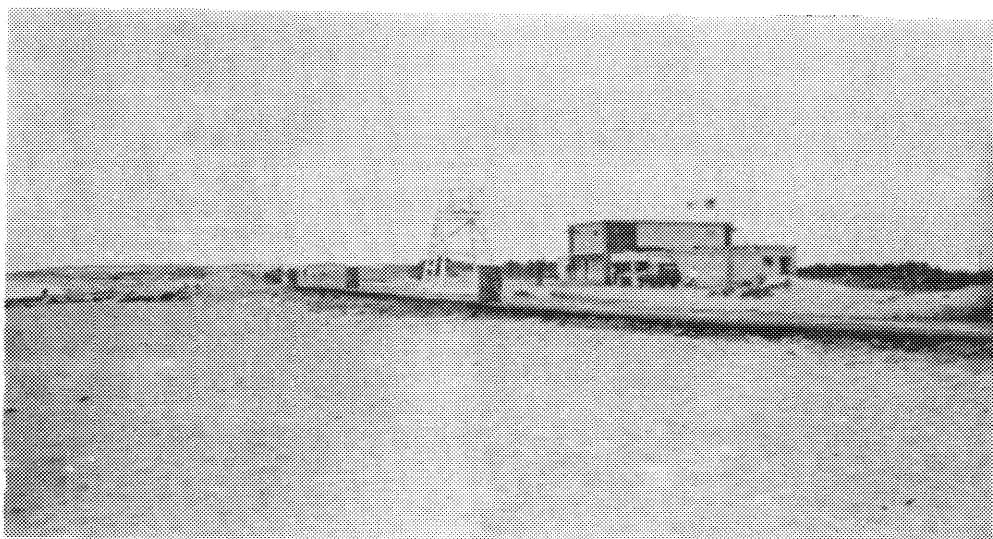


Fig. 15 Provincetown (new) Beach, Provincetown. 28 August 1958 - Bath house and facilities near south end of developed beach.

28. Brewster Bluffs, Brewster. - Details of this plan are shown on Plate 23. The plan consists of placing 150,000 cubic yards of sand along 5,000 feet of beach fronting private property. It is estimated that replenishment of losses of about 1,000 cubic yards of sand per year will be required.

29. Eastham. - Details of this plan are shown on Plate 23. For convenience this plan is divided into two projects, one for the 1,521 feet of town-owned property at Thumpertown (which included 500 feet now being obtained) and the second for 8,000 feet of frontage which is privately owned except at two street ends. The project at Thumpertown consists of one groin constructed of about 1,400 tons of stone and about 50,000 cubic yards of sand fill. The project for the private property consists of 8 groins constructed of about 11,200 tons of stone and direct placement of about 260,000 cubic yards of sand fill. The groins should be constructed with cover stone ranging from 2 to 4 tons on the seaward 200 feet and 1 to 2 tons on the remainder. If it is desired to construct the project in small segments, the smallest segment that should be considered is the construction of one groin and the placement of about 30,000 cubic yards of sand to the south of it.

30. An alternative to the above plan consisting of groins alone should be investigated. This can be accomplished by constructing one groin at the north end of the problem area and noting if filling occurs at a reasonable rate without damage to the shore to the north. If this groin is successful further construction of groins could be accomplished, progressing southward. It is considered that one groin, or possibly two depending on rate of filling, would be the maximum that may be constructed during a one-year period.

31. Indian Neck, Wellfleet. - The light protection constructed by residents of the area appears to furnish some protection and accretion is occurring at the breakwater at the north end. A low groin at the north end of the cottage area would raise the berm elevation and provide the additional protection needed. A plan and cross-section of the proposed groin is shown on Plate 23.

32. Pilgrim Beach, Truro. - Details of this plan are shown on Plate 23. The problem at Pilgrim Beach is the existence of very narrow beaches along about 8,000 feet of shore along the southerly end of the reach and excessive shoaling at the northerly end. The most feasible plan for this area appears to be the construction of 8 groins, each about 280 feet long and spaced about 1,000 feet apart. It is estimated that the construction will require about 20,000 tons of stone. Cover stone for the groins should weigh 4 to 6 tons each. Construction should start at the north end of the reach, and progress southward. Groin construction should be limited to not more than 2 groins each year.

33. Provincetown Beach, Provincelands. - This beach is developed for about 4,000 feet. However, the principal damage is occurring in the southerly 1,600 feet of shore fronting the bath house. The most feasible plan for this beach consists of construction of 2 new groins and raise and extend 2 groins requiring about 21,500 tons of stone, direct placement of about 120,000 cubic yards of sand and construction of 1,200 feet of precast concrete seawall. The groins should be about 400 feet apart, have side slopes of 1 on 2 and be constructed with cover stone weighing 6 to 8 tons each along the seaward 200 feet and 3 to 5 tons on the remainder.

34. Initially the sea wall and groins should be constructed and observed deferring placement of sand fill. If experience shows that littoral drift is insufficient to fill the groins naturally, then sand fill should be placed.

V. ECONOMIC ANALYSIS

35. General. - Eight reaches in the study area were designated for detailed study. Town Neck Beach, Thumpertown Beach and Provincetown Beach were found eligible for Federal assistance in the cost of construction of protection and improvement. The benefits to be obtained from protection or improvement of the remainder of the beaches were all private or the public benefit was too small to be significant and were therefore considered ineligible for Federal aid under Public Law 826, 84th Congress. The first cost and annual charges were estimated for each of these areas. Benefits were estimated only for the three areas eligible for Federal aid under Public Law 826, 84th Congress. The frontage at Eastham is divided into two projects, consisting of the public shore at Thumpertown and the private adjacent beach to the north.

36. Estimates of First Cost. - Estimates of first cost have been made on basis of July 1959 price levels obtained from recent bids on comparable work. It is considered that sand would be obtained from nearby land sources and trucked to the site and that local stone would be used in the structures. Details are given in Appendix F. The estimated cost of construction of the plans of protection for the 6 areas are given below:

- a. Town Neck Beach:
Beach widening, 165,000 cubic yards of sand fill; raise Cape Cod Canal jetty, 1,400 tons of stone \$181,000
- b. Spring Hill Beach:
Stock pile, 2,500 feet long, 266,000 cubic yards of sand fill. 271,000

- c. Brewster Bluffs:
Beach widening 150,000 cubic yards of
sand fill. \$134,000
- d. Thumpertown Beach:
Beach widening, 50,000 cubic yards sand
fill; 1 groin, 1,400 tons stone 54,000

- e. Eastham Private Beaches:
 (1) Beach widening, 260,000 cubic yards sand fill; 8 groins, 11,200 tons stone \$297,000
 (2) 1,000 foot segment of (1) 37,000
- f. Indian Neck:
 Construction 1 groin, 300 tons of stone 2,200
- g. Pilgrim Beach:
 Groin construction, 20,000 tons of stone 113,000
- h. Provincetown Beach:
 Beach widening, 120,000 cubic yards of sand; 4 groins, 21,500 tons of stone; 1,200 ft. concrete seawall 279,000

37. Apportionment of Costs. - Apportionment of cost is made in accordance with Public Law 826, 84th Congress. Three Federal projects are developed at Town Neck Beach in Sandwich, the publicly owned portion of the beach at Thumpertown in Eastham, and at the state owned beach in Provincetown. At Town Neck Beach the modification of the Federal jetty is apportioned all Federal since it protects 100 feet of Federally owned shore and benefits the Federal navigation project, the remainder as one-third Federal. In addition one-third of the cost of periodic nourishment of Town Neck beach is apportioned as Federal cost. The estimated amount of sand replenishment required is 4,000 cubic yards per year. The Federal share of this cost is estimated to be about \$1,000 annually. A section of undeveloped shore, 1,100 feet in length, is included but its protection is considered incidental since it is necessary to protect this reach to provide a logical plan for the remainder of the unit. The other two projects are entirely on non-Federal public lands. Apportionment of costs of construction for the three projects follows:

<u>Project</u>	<u>Item</u>	<u>Apportionment</u>		<u>Total</u>
		<u>Federal</u>	<u>Non-Federal</u>	
Town Neck Beach	Raise jetty	\$10,000	\$ - -	\$10,000
	Fill	57,000	114,000	171,000
	Total	67,000	114,000	181,000
Thumpertown Beach (Eastham)	Groin & Fill	18,000	36,000	54,000
Provincetown Beach	Groins, Fill and Seawall	93,000	186,000	279,000
Total		\$178,000	\$336,000	\$514,000

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38. Annual Charges. - Interest and amortization are computed on investment required which includes construction costs and preauthorization costs. Preauthorization costs are that portion of the cooperative study cost used to develop the project and was shared equally by the Federal Government and local interests. Interest rates used were 2.5 percent for Federal investments and 3 percent for non-Federal. Amortization was based on these same interest rates and a project life of 50 years. Investment costs and annual charges for the three projects recommended for Federal aid follow. Details are given in Appendix F.

Investment

Project	Interest	Construction Cost	Preauthorization Cost	Total Investment
Town Neck	Federal	\$67,000	\$1,500	\$68,500
Beach	Non-Federal	114,000	1,500	115,500
	Total	181,000	3,000	184,000
Thumpertown	Federal	18,000	1,200	19,200
	Non-Federal	36,000	1,200	37,200
	Total	54,000	2,400	56,400
Provincetown	Federal	93,000	1,000	94,000
	Non-Federal	186,000	1,000	187,000
	Total	279,000	2,000	281,000

Annual Charges

Project	Charge	Federal	Non-Federal	Total
Town Neck	Interest	\$1,700	\$3,500	\$5,200
Beach	Amortization	700	1,000	1,700
	Periodic Nourishment	1,000	2,000	3,000
	Maintenance	100	-	100
	Total	3,500	6,500	10,000
Thumpertown	Interest	500	1,100	1,600
	Amortization	200	300	500
	Maintenance	-	800	800
	Total	700	2,200	2,900
Provincetown	Interest	2,300	5,600	7,900
	Amortization	1,000	1,600	2,600
	Maintenance	-	2,300	2,300
	Total	3,300	9,500	12,800

39. Estimates of Benefits. - The two general types of benefits that would result from the projects are elimination of direct damages and recreational benefits. Direct damages eliminated include loss of land, buildings, parking areas and streets and elimination or reduction in maintenance of economically justified existing structures. Recreational benefit is based on increased usage of the project area because of the improvement, considering a desirable space requirement of 75 square feet per person and a monetary benefit of \$0.25 per visit. Details on benefits are given in Appendix G. A summary of the estimated benefits follows:

<u>Project</u>	<u>Direct Damages Prevented</u>	<u>Recreational Benefits</u>	<u>Total Benefits</u>
Town Neck Beach	\$10,000	\$3,300	\$13,300
Thumpertown	350	9,400	9,750
Provincetown Beach	8,400	11,900	20,300

40. Justification of Improvements. - In addition to the evaluated tangible benefits, there is an important intangible benefit applicable to each of the three beaches. This is the increased attractiveness of the towns involved to the tourist trade. Beaches are a significant factor in the economy of all Cape Cod towns. A comparison of evaluated benefits, annual charges and the benefit/cost ratio for each project follows:

<u>Project</u>	<u>Benefits</u>	<u>Annual Charges</u>	<u>B/C Ratio</u>
Town Neck Beach	\$13,300	\$10,000	1.3
Thumpertown Beach	9,750	2,900	3.4
Provincetown Beach	20,300	12,800	1.6

41. Interests. - In the three project areas, there is only one small length of beach, 100 feet long at Town Neck Beach, in Federal ownership. It is assumed that the modification of the jetty will furnish the protection to this property. The remainder of the shore, except the privately owned land for which the protection is incidental to the Town Neck Beach project, is in non-Federal public ownership. Private benefit estimated at Town Neck Beach is the elimination of private property loss which would occur after the public land has eroded away. Various types of benefits are classified below:

<u>Project</u>	<u>Type of Annual Benefit</u>		
	<u>Federal</u>	<u>Non-Federal Public</u>	<u>Private</u>
Town Neck Beach	\$800	\$7,900	\$4,900*
Thumpertown Beach	-	2,900	-
Provincetown Beach	-	20,300	-

* Results from protection of public shore.

42. Coordination with Other Agencies. - Close coordination has been maintained with the Division of Waterways, Massachusetts Department of Public Works, the cooperating agency, throughout the study. Town officials have been contacted and problems discussed. The cooperating agency and Selectmen of the Towns involved have been informed of the findings and recommendations contained in this report. They consider the report satisfactory and that the proposed plans of protection and improvement are desirable and necessary. Officials of the Town of Sandwich also stated that they considered that raising and lengthening the west jetty of Sandwich Harbor would aid in protecting Town Neck Beach to the west which is being developed by the Town for public use. In regard to the proposed projects at Town Neck Beach, Thumpertown Beach and Provincetown State Beach, the cooperating agency reports that the conditions which are required in connection with Federal participation on the projects, exclusive of financial requirements, will be fulfilled. They also state that they will recommend to the legislative branch that financial requirements be fulfilled. In no case in the past has the Legislature failed to make funds available for cooperative projects of this nature. The requirements upon which Federal participation is contingent are given in paragraph 47.

43. Plans for protection and improvement developed by this study were reviewed by Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, U.S. Department of the Interior and by the Division of Marine Fisheries, Department of Natural Resources of the Commonwealth of Massachusetts. The agencies stated that review of the plans indicated that the projects would not adversely affect commercial or sport fisheries and wildlife resources in the area involved.

VI CONCLUSIONS AND RECOMMENDATIONS

44. Conclusions. - The Division Engineer concludes that the following are practicable plans for protection and improvement of shore areas which merit consideration, all shown on Plate 23.

a. Town Neck Beach: Widening about 6,500 feet of beach to a 125-foot width by direct placement of suitable sand fill and raising the inshore end of the existing Cape Cod jetty.

b. Spring Hill Beach: Widening about 14,000 feet of beach to a 125-foot width by placement of suitable sand fill in a stock pile at the westerly end of the beach.

c. Brewster Bluffs: Widening about 5,000 feet of beach to a 125-foot width by direct placement of suitable sand fill.

d. Eastham Beaches (including Thumpertown Beach): Widening about 9,500 feet of beach to a 125-foot width by direct placement of suitable sand fill and construction of 9 groins generally about 300 feet long. The placement of sand fill to be deferred until it is ascertained if groins fill naturally at a reasonable rate.

e. Indian Neck: Construction of 1 groin about 150 feet long.

f. Pilgrim Beach: Widening about 8,000 feet of beach to a 125-foot width by construction of 8 stone groins generally about 280 feet long.

g. Provincetown Beach: Widening about 1,600 feet of beach to a 125-foot width by direct placement of suitable sand fill, construction of 4 stone groins generally about 340 to 380 feet long and construction of a concrete seawall about 1,200 feet long. The placement of sand fill to be deferred until it is ascertained if groins fill naturally at a reasonable rate.

45. The projects considered for the public Town Neck Beach, Thumpertown Beach in Eastham and Provincetown Beach are economically justified by evaluated benefits. The nature and amount of benefits for Thumpertown Beach and Provincetown Beach are sufficient to warrant the maximum one-third participation by the United States in the first cost of construction in accordance with the provisions of Public Law 826, 84th Congress. Conditions at Town Neck Beach are such as to warrant raising of the inshore end of the Federal jetty at Cape Cod Canal wholly at the expense of the United States and maximum one-third participation by the United States in the first cost of construction of the remainder of the project. It is advisable for the United States to adopt projects authorizing Federal participation to the extent of one-third the first cost of projects at Thumpertown Beach and Provincetown Beach and to the extent of all the cost of jetty modification and one-third of the first cost of construction of the remainder of a project at Town Neck Beach. In addition, it is advisable for the United States to participate to the extent of one-third the cost of periodic nourishment of Town Neck Beach. There is insufficient general public interest in the projects considered for other sections of the study area to warrant Federal participation in the costs of construction of projects. Additional information on recommended and alternative projects called for by Senate Resolution 146, 85th Congress, 1st Session, adopted 28 January 1958 is contained as an attachment to this report.

46. Recommendations. - The Division Engineer recommends that protective measures which may be undertaken by local interests based on their own determination of economic justification be accomplished generally in accordance with methods proposed and projects considered in this report. The Division Engineer further recommends that the United States adopt projects authorizing Federal participation by the

contribution of Federal funds in an amount equal to one-third the first costs of construction of the following projects generally as shown on Plate 23.

a. Thumpertown Beach, Eastham. - Widening approximately 1,500 feet of beach to a 125-foot width by direct placement of suitable sand fill and construction of a groin about 300 feet long.

b. Provincetown Beach, Provincetown. - Widening about 1,600 feet of beach to a 125-foot width by direct placement of suitable sand fill, construction of 4 groins ranging from 340 to 380 feet in length and construction of a concrete seawall. The placement of the sand fill to be deferred until it is ascertained if the groins fill naturally at a reasonable rate.

c. Town Neck Beach, Sandwich. - Widening about 6,500 feet of beach to a 125-foot width by direct placement of suitable sand fill

In addition, it is recommended that the United States adopt a project authorizing the raising of the inshore end of the Federal jetty at Cape Cod Canal wholly at Federal expense and authorizing Federal participation in amount equal to one-third the costs of periodic nourishment of Town Neck Beach for an initial period of ten years from the year of completion of the initial work.

47. The recommended Federal participation is subject to the conditions that local interests will:

a. Obtain approval by the Chief of Engineers prior to commencement of work, of detailed plans and specifications for the project or suitable portions thereof, and also the arrangements for prosecuting the work.

b. Assure continued public ownership of the shore upon which the amount of Federal participation is based, and its administration for public use during the economic life of the project.

c. Assure maintenance, repair and beach nourishment during the economic life of the works as may be required to serve the intended purposed.

d. Assure that water pollution that would endanger the health of bathers will not be permitted.

48. The estimated amounts of Federal participation in the first costs of the projects, in accordance with the foregoing recommendations are \$67,000 for Town Neck Beach, \$18,000 for Thumpertown Beach and \$93,000 for Provincetown Beach. The estimated Federal annual cost of periodic nourishment of Town Neck Beach is \$1,000.

30 Incls
7 Appendicies (A-G)
23 Plates.

ALDEN K. SIBLEY
Brigadier General, U.S. Army
Division Engineer

APPENDIX A

DESCRIPTION AND COMPOSITION OF BEACHES

1. General.- Detailed descriptive data and data on composition of the shore of Cape Cod Bay between Cape Cod Canal and Race Point in Provincetown were obtained from field inspection, field survey, ground and aerial photographs, topographic maps, coast charts and from discussion with, and information furnished by officials of the Commonwealth and the towns involved. The detailed field inspection was made in May and August 1958 and field surveys were made during the period July - November 1958. Description by increments of shore is given beginning at the Canal and progressing toward Race Point. Beach width, unless otherwise designated, is the usable width above the plane of mean high water.

2. Profiles and Beach Samples. - A total of 40 profiles were made at seven areas of specific interest. Plots of selected profiles are shown on Plates 21 and 22. Surface sand samples were taken, as shown on Table A-1 following, at the dune, between the dune and mean high water, at mean high water, mid-tide elevation, mean low water and the 3, 6 and 12-foot depths along the line of 14 of the 40 profiles.

3. Detailed Description. - Detailed description of the shore of Cape Cod Bay between Cape Cod Canal and Race Point follows. Numbers in parenthesis following structure names are identification numbers of the structures shown on Plates 2 - 10. Elevations are referred to the plane of mean low water unless otherwise specified.

a. Town of Sandwich

(1) Cape Cod Canal South Jetty Southerly:

- A. Extent: Approximately 1,000 feet.
- B. Ownership: 100' Federal, Remainder Private.
- C. Beach Use: Bathing Beach and jetty right-of-way.
- D. Public Facilities: None
- E. Beach Width Above High Water: Generally 5 feet in front of bank.
- F. Composition of Shore: Gravel, cobble and sand at west, fine sand with some gravel at east.
- G. Protective Structures: Cape Cod Canal south jetty (1), 600 feet long, jetty in fair condition. Stone groin (2) about 200 feet long located about 1,000 feet east of jetty, groin in fair condition with some unraveling of stone between high water and mid-tide.

TABLE A-1. SAND SAMPLE ANALYSIS

Profile No. & Beach Name	Position of Sam- ple on Profile	Median Dia. in mm	Characteristics of Material in Percent			
			.074-.42	.42-2.0	2.0-4.7	Over
			mm Fine Sand	mm Med. Sand	mm Coarse Sand	4.7 mm Gravel
3						
Town Neck	Dune	0.42	30	70	-	-
Beach	Dune HW	0.41	40	59	1	-
Sandwich	MHW	0.41	60	39	1	-
	MT	0.59	23	74	2	1
	MLW	0.76	23	60	5	12
	-3	0.42	50	47	2	1
	-6	0.42	50	48	2	-
	-12	0.37	75	24	1	-
12						
Spring Hill	Dune	0.42	50	50	-	-
Beach	Dune HW	0.87	8	61	5	26
Sandwich	MHW	0.55	27	61	4	8
	MT	0.33	22	25	6	47
	MLW	0.87	15	52	10	23
	-3	0.78	18	47	13	22
	-6	0.80	2	96	2	-
	-12	0.49	37	62	1	-
16						
East of	Dune	0.6	35	65	-	-
Sesuit Hbr.	Dune HW	0.5	61	39	-	-
Dennis	MHW	0.3	92	8	-	-
	MT	Silt	27	3	-	-
	MLW	0.2	55	12	-	-
	-3	0.3	97	3	-	-
	-6	0.2	94	6	-	-
	-12	0.7	12	88	-	-
19						
East of	Dune	0.6	29	71	-	-
Sesuit Hbr.	Dune HW	0.5	42	58	-	-
Dennis	MHW	0.5	25	75	-	-
	MT	0.3	98	2	-	-
	MLW	0.2	84	4	1	11
	-3	0.2	93	3	-	-
	-6	0.2	90	10	-	-
	-12	0.5	45	55	-	-

Table A-1 Continued

Profile No. & Beach Name	Position of Sam- ple on Profile	Median Dia. in mm	Characteristics of Material in Percent			
			0.74-.42	.42-2.0	2.0-4.7	Over
			mm Fine Sand	mm Med. Sand	mm Coarse Sand	4.7 mm Gravel
20 Bluff Area Brewster	Dune	0.5	48	52	-	-
	Dune HW	0.6	19	80	1	-
	MHW	0.5	50	50	-	-
	MT	0.2	98	2	-	-
	MLW	0.2	97	3	-	-
	-3	0.3	96	4	-	-
	-6	0.2	98	2	-	-
	-12	0.5	41	59	-	-
12 Bluff Area Brewster	Dune	0.5	40	60	-	-
	Dune HW	0.6	49	81	-	-
	MHW	0.4	55	45	-	-
	MT	0.3	91	9	-	-
	MLW	0.2	98	2	-	-
22 Bluff Area Brewster	Dune	0.5	31	69	-	-
	Dune HW	0.6	24	76	-	-
	MHW	0.8	8	91	1	-
	MT	0.3	75	25	-	-
	MLW	0.4	60	40	-	-
	-2.5	0.3	98	2	-	-
A-1 Eastham	Dune	0.42	50	44	3	3
	Dune HW	0.42	50	49	1	-
	MHW	0.87	5	87	7	1
	MT	0.60	15	80	4	1
	MLW	0.33	78	22	-	-
A-2 Eastham	Dune	0.35	60	35	3	-
	Dune HW	0.61	13	86	1	-
	MHW	0.54	18	82	-	-
	MT	0.47	28	71	1	-
	MLW	0.31	87	13	-	-
A-3 Eastham	Dune	0.30	68	31	-	-
	Dune HW	0.54	14	86	-	-
	MHW	0.67	5	93	1	1
	MT	0.52	15	83	2	-
	MLW	0.31	78	22	-	-

Table A-1 Continued

Profile No. & Beach Name	Position of Sam- ple on Profile	Median Dia. in mm	Characteristics of Material in Percent			
			0.74-.42 mm Fine Sand	.42-.2.0 mm Med. Sand	2.0-4.7 mm Coarse Sand	Over 4.7 mm Gravel
23	Dune	0.78	12	81	4	3
Pilgrim	Dune HW	1.4	2	66	32	-
Beach	MHW	1.3	1	99	-	-
Truro	MT	1.4	4	85	9	2
	MLW	4.0	9	37	6	48
	-3	0.43	35	64	1	-
	-6	0.42	50	49	1	-
	-12	0.38	92	8	-	-
34	Dune	0.57	3	96	1	-
Pilgrim	Dune HW	0.57	1	96	3	-
Beach	MHW	0.72	0	98	2	-
Truro	MT	1.2	0	87	11	2
	MLW	0.91	2	91	7	-
	-3					
	-6	0.65	1	96	3	-
	-12	0.70	4	94	2	-
35	Dune	0.82	9	89	2	-
Provincetown	Dune HW	0.72	8	84	1	3
Beach	MHW	0.82	3	97	-	-
Provincetown	MT	1.1	1	99	-	-
	MLW	1.2	0	99	1	-
	-3	1.6	0	95	3	2
37	Dune	0.76	0.7	85	12	4
Provincetown	Dune HW	0.72	0.4	99	-	-
Beach	MHW	0.90	0	99	1	-
Provincetown	MT	0.99	0	77	17	6
	MLW	0.99	1	99	-	-
	-3	1.5	0	100	-	-
	-6	1.2	0	96	2	2
	-12	1.6	0	80	11	9

- H. Character of Development: None. Small Coast Guard installation well back of beach.
- I. Damage: Except for northerly 200 feet there is apparent recession of the small dune back of beach.

(2) 1000 Feet South of Cape Cod Canal to Sandwich Harbor:

- A. Extent: Approximately 5,000 Feet.
- B. Ownership: 200' private, remainder Town-owned frontage.
- C. Beach Use: Generally resident bathing.
- D. Public Facilities: Two parking lots and small bathhouse near center of reach.
- E. Beach Width Above High Water: Generally 5 to 20 feet then reduced to 0 about 1500 feet southward, thence widening to about 200 feet at southeast end. Berm very flat back to bank.
- F. Composition of Shore: At west end fine sand above mid-tide and cobbles and boulders below, about 1500 feet southward gravel, cobbles and boulders to dune, (eroded headland), east of boulder section is medium sand becoming coarser then mixed with gravel at southeast end. At west end beach backed by clay bluff about 5 feet high with small dune on top, about 1500 east clay blends into beach, then dune to southeast end of section.
- G. Protective Structures: 5 stone groins (3-7) spaced 500 to 600 feet apart and about 150-200 long, 5 foot top width and seaward end at about elevation +2. Westerly groin located about 2,500 feet east of west end of reach. West jetty of Sandwich Harbor (8) at east end of reach. Inner 200 feet of jetty of concrete caisson and outer 150 feet stone mound.
- H. Character of Development: Small summer cottages to about center of reach then no development.
- I. Damage: Recession of bank or dunes and slight flanking at groins. Stone in groin (5) slightly scattered by erosion of beach on west side at about mid-tide elevation.

(3) Sandwich Harbor to 2,000 feet East:

- A. Extent: Approximately 2,000 feet.
- B. Ownership: 275 feet public, Remainder private.
- C. Beach Use: Residential bathing along easterly 1,000 feet.
- D. Public Facilities: None.
- E. Beach Width Above High Water: About 100 feet to dunes.
- F. Composition of Shore: Medium sand with some fine gravel.

- G. Protective Structures: East Jetty of Sandwich Harbor (9), a short stone jetty.
- H. Character of Development: Small summer cottages.
- I. Damage: Dune retreating.

(4) 2,000 Feet East of Sandwich Harbor to Scorton Harbor:

- A. Extent: Approximately 12,500 feet.
- B. Ownership: 100 feet public, remainder private.
- C. Beach Use: Residential bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: Approximately 100 feet.
- F. Composition of Shore: To groin(3) medium sand with gravel below high water and medium to fine sand above. East of groin 3 medium sand mixed with gravel.
- G. Protective Structures: 17 Stone groins (10-26) ranging in length from about 75 feet to 200 feet and spaced about 600 to 700 feet apart. Groins have a top width of 5 feet and extend to about 2 feet above mean low water. Groins in fair to good condition except (12-14) in fair to poor condition. West jetty of Scorton Hbr. (27), about 750 feet east of groin (26), constructed of stone.
- H. Character of Development: Medium to small summer residences.
- I. Damage: House foundation undermined. Severe dune cutting to groin (16) then less cutting. Groins as described in section G.

(5). Scorton Harbor to Town Line:

- A. Extent: Approximately 13,000 feet.
- B. Ownership: Private.
- C. Beach Use: Bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 25 to 75 feet fronting low dunes at west and high dunes at east.
- F. Composition of Shore: Fine to medium sand.
- G. Protective Structures: Stone jetty at Scorton Harbor.
- H. Character of Development: Small number of medium size summer residences.
- I. Damage: Some toe erosion at dunes.

b. Town of Barnstable

(1). Sandy Neck Town Beach:

- A. Extent: 3,000 feet.
- B. Ownership: Town (public).

- C. Beach Use: Bathing Beach (free to residents, 50¢ to others).
- D. Public Facilities: Paved Parking Area, picnic tables, waste receptacles, snack bar, beach buggy rides.
- E. Beach Width Above High Water: 75 to 100 feet.
- F. Composition of Shore: Fine sand above High Water, fine sand and fine gravel at High Water line, larger gravel mixed with fine sand below High Water.
- G. Protective Structures: None.
- H. Character of Development: Public bathing beach.
- I. Damage: Some damage to toe of dune.

(2) Sandy Neck:

- A. Extent: Approximately 6 miles.
- B. Ownership: Town of Barnstable.
- C. Beach Use: Bathing, fishing and beach buggy use.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 100 to 150 feet fronting dunes at west to no width at outer end.
- F. Composition of Shore: Fine uniform sand mixed with gravel.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: Dunes generally wave cut.

c. Town of Dennis

(1) Bass Hole to 1 Mile East:

- A. Extent: Approximately 5,000 feet.
- B. Ownership: Public
- C. Beach Use: Bathing and beach buggy use.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 40 to 50 feet to dune.
- F. Composition of Shore: Fine uniform sand with dunes behind. Scarp 5 feet high at westerly end and 12 feet high at easterly.
- G. Protective Structures: One stone groin (29) about 100 feet long in very poor condition located about 200 feet from easterly end of reach. A second groin (30) located at east end of the reach is about 150 feet long and in fair condition.
- H. Character of Development: Small summer cottages at east end.
- I. Damage: In some cases dune has migrated around cottages constructed too close to dune. Erosion of dune. Window breakage by recent storms.

(2) 1 Mile South of Bass Hole to Nobscusset Point:

- A. Extent: Approximately 10,500 feet.
- B. Ownership: Private.
- C. Beach Use: Resident bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 50 to 60 feet along westerly 2,500 feet then widening to 60 to 150 feet then narrowing toward east end. Toe of dune about 2 feet above high water.
- F. Composition of Shore: Fine sand at west, becoming coarser easterly then mixed with gravel near east end. Boulders strewn on beach and nearshore along easterly 2,000 feet, a clay layer becomes visible beneath the dune about 1,000 feet east of the west limit. This clay layer increases in height until about 1 mile from west limit the entire bluff becomes clayey glacial till.
- G. Protective Structures: A stone groin (31) about 150 feet long is located about 500 feet from west end of reach.
- H. Character of Development: Small residences along westerly $\frac{1}{2}$ mile then medium to large residences from thereon.
- I. Damage: Severe erosion and migration of dune at west end and caving of bluff to east. At west cottage grounds, driveways, etc. covered by sand. Some damage to cottages, steps, and shorefront facilities.

(3) Nobscusset Point and Harbor:

- A. Extent: Approximately 900 feet.
- B. Ownership: Public (Town of Dennis).
- C. Beach Use: Bathing and small boat mooring.
- D. Public Facilities: Small bath house and paved parking area.
- E. Beach Width Above High Water: 40 to 60 feet.
- F. Composition of Shore: Fine well-graded sand with some cobbles above high water.
- G. Protective Structures: 2 stone groins (32 - 33) about 150 feet long and 500 feet apart, the first at west end of reach. Stone mound revetment (34) about 1,000 feet long extending from west end of reach to timber pile breakwater forming small boat harbor (very shallow). Low stone revetment (35) about 200 feet long fronting parking area near east end of reach. Stone groin (36), about 100 feet long and probably built by local people near east limit of public beach.
- H. Character of Development: Recreational area development.
- I. Damage: No visible damage.

(4) NobsCUSset Point to 3,500 feet Eastward:

- A. Extent: Approximately 3,500 feet.
- B. Ownership: Private
- C. Beach Use: Resident Bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: About 50 feet at west and 25 feet at east end.
- F. Composition of Shore: Fine to medium well graded sand at west and coarser to east. Low dune behind beach with till visible at toe in some locations.
- G. Protective Structures: Stone revetment fronting one lot near center of reach.
- H. Character of Development: Medium to small residential summer dwellings at west. Undeveloped along east half.
- I. Damage: Dune erosion throughout. About the middle of the reach, an 8-inch drain discharges from top of dune causing damage to face.

(5) Sesuit Neck:

- A. Extent: Approximately 3,700 feet.
- B. Ownership: Private.
- C. Beach Use: Resident Bathing.
- D. Public Facilities: None. (One private beach house near center of area).
- E. Beach Width Above High Water: Irregular beach widths ranging from 25 to 40 feet.
- F. Composition of Shore: 700 feet of eroded headland debris, 1,000 feet of fine sand pocket beach, 1,000 feet of remains of eroded headland, 700 feet of fine well graded sand beach, then about 300 feet of cobbles and boulders from eroded headland.
- G. Protective Structures: None.
- H. Character of Development: A large estate located near center of segment then medium residences to east end of reach.
- I. Damage: Bluff and dune erosion.

(6) West Side Sesuit Harbor:

- A. Extent: 1,000 feet.
- B. Ownership: 275 feet public, remainder private.
- C. Beach Use: Bathing Beach.
- D. Public Facilities: Small boat harbor.
- E. Beach Width Above High Water: 0 at west end to about 50 feet at jetty.
- F. Composition of Shore: Fine Sand.

G. Protective Structures: Stone revetment (37) about 500 feet long at west end. West jetty (38) of Sesuit Harbor at east end.

H. Character of Development: Medium residences.

I. Damage: None visible.

(7) East Side Sesuit Harbor (Quivett Neck):

A. Extent: Approximately 3,000 feet.

B. Ownership: 2,500 feet public, remainder private.

C. Beach Use: Resident Bathing.

D. Public Facilities: None.

E. Beach Width Above High Water: About 60-70 feet at west end and 25 feet at east.

F. Composition of Shore: Medium sand with some gravel except at eroded headland at east limit. Dunes behind beach except at till headland at east end.

G. Protective Structures: Stone jetty (39) on east bank of Sesuit Creek (Sesuit Harbor). 3 stone groins (40-42) each about 150 feet long, westerly one (40) about 500 feet east of jetty and others about 400 feet apart.

H. Character of Development: Medium summer residences.

I. Damage: Dune retreating and beach loss.

(8) Quivett Neck:

A. Extent: Approximately 700 feet.

B. Ownership: Private.

C. Beach Use: None.

D. Public Facilities: None.

E. Beach Width Above High Water: 50 to 75 feet.

F. Composition of Shore: Cobbles and boulders except above High Water and in pocket beach fronting the swale between two headlands.

G. Protective Structures: None.

H. Character of Development: Few medium summer dwellings.

I. Damage: Erosion of bluff.

(9) Quivett Neck:

A. Extent: Approximately 2,000 feet.

B. Ownership: Private.

C. Beach Use: Probable light resident bathing.

D. Public Facilities: None.

E. Beach Width Above High Water: 25 to 30 feet.

F. Composition of Shore: This is a barrier beach, of medium well graded sand, between two till headlands. Low dunes are located along the rear of the beach.

- G. Protective Structures: None.
- H. Character of Development: None along shore.
- I. Damage: Erosion of headlands.

(10) Quivett Neck East End:

- A. Extent: Approximately 3,000 feet to Town line at Quivett Creek.
- B. Ownership: Private.
- C. Beach Use: None apparent.
- D. Public Facilities: None
- E. Beach Width Above High Water: 50 feet.
- F. Composition of Shore: Fine to medium well graded sand above midtide. Eroded marsh area below midtide (apparently the ocean has advanced over a marsh area).
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: Negligible.

d. Town of Brewster

(1) Quivett Creek to Stony Brook:

- A. Extent: About 2,100 feet.
- B. Ownership: Private.
- C. Beach Use: None apparent.
- D. Public Facilities: None apparent.
- E. Beach Width Above High Water: Approximately 15 feet.
- F. Composition of Shore: Mounded dune of fine to medium sand near center surrounded by marsh. Marsh offshore.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: None.

(2) Town Beach:

- A. Extent: 1,000 feet.
- B. Ownership: Public (Town).
- C. Beach Use: Public Bathing.
- D. Public Facilities: Parking area at end of Duck Farm Lane.
- E. Beach Width Above High Water: 15 feet.
- F. Composition of Shore: Fine to medium sand above revetment and small fillet at groin. Offshore appears to be marsh with some sand.
- G. Protective Structures: Stone revetment (43) along entire frontage with stone groin (44) about 150 feet long at the east end of the segment.
- H. Character of Development: Bathing area of limited desirability.
- I. Damage: None apparent.

(3) Easterly of Town Beach:

- A. Extent: 6,500 feet.
- B. Ownership: 112 feet public, remainder private.
- C. Beach Use: Resident bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: About 70 feet.
- F. Composition of Shore: Fine to medium sand beach. Cobbles and boulders in offshore beginning about 700 feet from east end and at east end where headland erosion left extensive residue.
- G. Protective Structures: 8 stone groins (45 - 52) each about 100 feet long and spaced 400 to 500 feet apart beginning about 2,000 feet from west end of segment. Stone revetment (53) 500 feet long extending east from groin (52).
- H. Character of Development: Scattered large to medium dwellings throughout except for smaller dwellings in a development about $3/4$ distance from west to east end.
- I. Damage: Minor bluff toe damage.

(4) Cobbs Pond and Myricks Pond Area:

- A. Extent: Approximately 5,500 feet.
- B. Ownership: 380 feet public, remainder private.
- C. Beach Use: Bathing.
- D. Public Facilities: Paved parking area for about 30 cars at west end.
- E. Beach Width Above High Water: 25 to 50 feet.
- F. Composition of Shore: Fine to medium sand mixed with some pea gravel and shells at west to medium to coarse sand at east. Small to very large boulders on beach at eroded headland near east end. Sand bars in near-shore running at angles to shore line.
- G. Protective Structures: Seven stone groins, (54 - 60) see plate for location. Groins ranging from 100 to 150 feet long with outer end at about mean low water. Structures in good condition.
- H. Character of Development: Medium size summer dwellings.
- I. Damage: Some cutting of bluff by storm waves near center of reach.

(5) East to Town Line:

- A. Extent: About 12,000 feet.
- B. Ownership: 350 feet public, remainder private.
- C. Beach Use: Bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 50 to 100 feet.

- F. Composition of Shore: Fine sand at mean low water to coarse sand about 2 feet above, then growing finer to fine sand at mean high water and above.
- G. Protective Structures: Six stone groins (61 and 63-67) ranging from 75 to 150 feet long. See Plates 5 and 6 for location. Revetment (62) about 200 feet long on west side of most westerly groin.
- H. Character of Development: Medium size summer homes except for development of small rental cottages at east end.
- I. Damage: Storm wave damage to dune especially near center of reach.

e. Town of Orleans:

(1) Skaket Beach:

- A. Extent: Approximately 3,500 feet.
- B. Ownership: About 1,100 feet public, remainder private.
- C. Beach Use: Bathing.
- D. Public Facilities: At public beach (Town), paved parking area (about 100 cars), refreshment stand and small dressing room.
- E. Beach Width Above High Water: About 100 feet.
- F. Composition of Shore: Fine sand.
- G. Protective Structures: None.
- H. Character of Development: 3 summer cottages and public beach.
- I. Damage: None.

(2) Little Namskakot Creek to Town Line (Rock Creek):

- A. Extent: Approximately 2,000 feet.
- B. Ownership: 280 feet public.
- C. Beach Use: Fishing harbor and small beach.
- D. Public Facilities: Wharf with parking on deck.
- E. Beach Width Above High Water: 50 to 150 feet.
- F. Composition of Shore: Fine to medium sand with growing vegetation.
- G. Protective Structures: Timber wharf with bituminous deck.
- H. Character of Development: Small fishing harbor and few homes.
- I. Damage: None.

f. Town of Eastham:

(1) Rock Creek to Herring River:

- A. Extent: Approximately 6,000 feet.
- B. Ownership: 1,000 feet public.

- C. Beach Use: None.
- D. Public Facilities: None.
- E. Beach Width Above High Water: Marsh area with surface slightly above mean high water.
- F. Composition of Shore: Coarse sand above and fine below mean high water.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: None.

(2) First Encounter Beach:

- A. Extent: Approximately 3,000 feet.
- B. Ownership: Town of Eastham (Public).
- C. Beach Use: Public bathing beach.
- D. Public Facilities: Paved parking area.
- E. Beach Width Above High Water: Approximately 100 feet.
- F. Composition of Shore: Medium sand above and fine sand below high water.
- G. Protective Structures: None.
- H. Character of Development: Public beach, no dwellings.
- I. Damage: None evident.

(3) First Encounter Beach to Cole Road:

- A. Extent: Approximately 3,000 feet.
- B. Ownership: Private except 150 feet at street end.
- C. Beach Use: Bathing (resident).
- D. Public Facilities: None.
- E. Beach Width Above High Water: Generally 25 to 30 feet.
- F. Composition of Shore: Medium sand above about 2 feet above mean low water then fine sand below. Dunes forming the back shore are generally sand with clay layer from toe to about 12 feet above mean low water.
- G. Protective Structures: None.
- H. Character of Development: Medium size and larger summer dwellings.
- I. Damage: Bluff or dune damage throughout the reach with greatest damage occurring at the highest dunes near the center. Damage is apparently due to storm waves at high tides as there was no evidence of surface runoff of groundwater seepage throughout the dune.

(4) Cole Road to Kingsbury Beach:

- A. Extent: Approximately 3,000 feet.
- B. Ownership: Private except for street end at Kingsbury Beach Road. Although public ownership consists of about 35 feet, public uses 200 to 300 feet.

- C. Beach Use: Bathing.
- D. Public Facilities: Paved parking area at Kingsbury Beach Road.
- E. Beach Width Above High Water: About 25 feet at Herring Brook increasing to about 50 feet at public beach.
- F. Composition of Shore: Medium to fine sand above about 1 foot above mean low water and very fine sand below.
- G. Protective Structures: None.
- H. Character of Development: Medium to small summer dwellings.
- I. Damage: Dune erosion along southerly half of reach.

(5) Kingsbury Beach to Thumpertown Beach:

- A. Extent: Approximately 2,000 feet.
- B. Ownership: Private except at north end, 1,500 feet of public ownership at north.
- C. Beach Use: Bathing.
- D. Public Facilities: Paved parking area at north end (est. 50 cars).
- E. Beach Width Above High Water: Approximately 60 feet.
- F. Composition of Shore: Medium sand.
- G. Protective Structures: None.
- H. Character of Development: Medium size summer dwellings.
- I. Damage: Bluff erosion at and near Thumpertown Road. No evidence of surface runoff.

(6) Thumpertown Beach to Campground Landing:

- A. Extent: approximately 2,300 feet.
- B. Ownership: Private except for 240 feet at north.
- C. Beach Use: Bathing.
- D. Public Facilities: Paved parking area at north (est. 50 cars).
- E. Beach Width Above High Water: Approximately 75 feet.
- F. Composition of Shore: Medium sand with shells, and mixed with coarse sand near parking lot.
- G. Protective Structures: None.
- H. Character of Development: Medium size dwellings.
- I. Damage: Sand bluff eroding. A 10-inch corrugated storm drain discharging at north end of reach has lowered beach about 18-inches at outflow stream.

(7) Campground Landing to Silver Spring Beach:

- A. Extent: Approximately 5,000 feet.
- B. Ownership: Private except about 200 feet frontage at north end and 6 rights-of-way to beach.
- C. Beach Use: Bathing.

- D. Public Facilities: Paved parking area at north end (about 200 feet by 200 feet).
- E. Beach Width Above High Water: 75 to 80 feet.
- F. Composition of Shore: Fine, generally well graded sand.
- G. Protective Structures: None.
- H. Character of Development: Medium dwellings.
- I. Damage: Bluff erosion throughout with houses very close to bluff edge. Catch basin from parking area discharges on bluff face about 5 feet below level of paving causing loss of bluff. Fill has been added to protect paved area.

(8) Silver Spring Beach to Town Line:

- A. Extent: Approximately 5,500 feet.
- B. Ownership: Private except for 150 feet near center of reach and 100 feet near north end.
- C. Beach Use: Bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 80 feet at south, about midway begins to narrow to 0 at north end.
- F. Composition of Shore: Fine sand except for some fine gravel intermixed along northerly 2,000 feet.
- G. Protective Structures: None.
- H. Character of Development: Medium to small summer dwellings scattered throughout reach.
- I. Damage: Storm cutting of dunes.

g. Town of Wellfleet

(1) Indian Neck (Wellfleet Harbor):

- A. Extent: Approximately 8,000 feet.
- B. Ownership: Apparently a public beach throughout although cottages scattered along backshore. Only access near north end.
- C. Beach Use: Bathing.
- D. Public Facilities: Paved parking area.
- E. Beach Width Above High Water: 10 to 40 feet fronting dunes and cliffs.
- F. Composition of Shore: Fine uniform sand.
- G. Protective Structures: Stone breakwater (68) about 1,000 feet long at north end of the point at north end of reach. Top width 6-8 feet, side slopes 1 on 1.5.
- H. Character of Development: Medium and small summer dwellings.
- I. Damage: Banks and dunes eroding at toe. Some cottages are close to edge. Some erosion noted across harbor along Mayo Beach, Great Island and Great Beach Hill.

(2) The Gut to Great Island:

- A. Extent: Approximately 2,800 feet.
- B. Ownership: Private.
- C. Beach Use: Very limited bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: Generally about 25 feet.
- F. Composition of Shore: Fine sand with some gravel about mid-tide elevation.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: Erosion of dunes behind beach.

(3) Wellfleet Town Beach:

- A. Extent: 700 feet.
- B. Ownership: Public.
- C. Beach Use: Bathing, sight seeing.
- D. Public Facilities: Paved parking area with stairs to beach below.
- E. Beach Width Above High Water: 25 to 35 feet.
- F. Composition of Shore: Fine sand with some gravel at mid-tide elevation.
- G. Protective Structures: Stone revetment (69) behind beach along entire frontage. Revetment about 15 feet high to about elevation 25 and composed of stones over 1 ton each.
- H. Character of Development: Bathing beach.
- I. Damage: None.

(4) Griffin Island:

- A. Extent: Approximately 4,200 feet.
- B. Ownership: Private except 1,200 feet south from Griffin Rd.
- C. Beach Use: Limited amount of bathing.
- D. Public Facilities: Paved parking area.
- E. Beach Width Above High Water: 25 to 30 feet.
- F. Composition of Shore: Fine sand with gravel at mid-tide elevation and slopes about 1 on 20. Near shore bars are noted about 500 feet seaward. Bluffs essentially fine to coarse sand with one or more stratae of red clay.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: Erosion of toe of bluffs.

(5) Griffin Island to Town Line:

- A. Extent: Approximately 4,500 feet.
- B. Ownership: Private.
- C. Beach Use: Resident Bathing.
- D. Public Facilities: None
- E. Beach Width Above High Water: 10 to 30 feet to dunes.
- F. Composition of Shore: Fine sand with small amount of gravel except for two small points near south end where sand becomes coarse then there are transverse bars composed of coarse sand, gravel and cobble.
- G. Protective Structures: None.
- H. Character of Development: None.
- I. Damage: Erosion of dunes.

h. Town of Truro:

(1) Town Line to Ryder Beach:

- A. Extent: Approximately 2,800 feet.
- B. Ownership: About 250 feet at north public (Ryder Beach), remainder private.
- C. Beach Use: Bathing.
- D. Public Facilities: Small inadequate paved parking area for about 15 cars.
- E. Beach Width Above High Water: About 25 feet at south increasing to 50 feet at north.
- F. Composition of Shore: Medium sand beach with flat berm from about 2 feet above mean high water. This reach and southward is a tombolo composed of Bound Brook Island, Griffin Island, Great Island, Great Beach Hill and the spit southward.
- G. Protective Structures: None.
- H. Character of Development: Relatively undeveloped. Several small cottages and bathing beach.
- I. Damage: Dunes eroding.

(2) Fisher Road to Ryder Beach Road:

- A. Extent: Approximately 7,300 feet.
- B. Ownership: Private.
- C. Beach Use: Limited bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 50 feet at south to 15 feet at north.
- F. Composition of Shore: Fine to medium sand beach fronting glacial sand bluffs.
- G. Protective Structures: None.
- H. Character of Development: Few scattered medium to large summer homes.
- I. Damage: Bluff eroding throughout.

(3) Fisher Road to Pamet River:

- A. Extent: Approximately 3,100 feet.
- B. Ownership: Private except at jetty at north and 40 feet wide street end at south end.
- C. Beach Use: Bathing at south and fishing Pamet River jetty.
- D. Public Facilities: Parking along Fisher Road.
- E. Beach Width Above High Water: 50 feet at south to about 15 feet about 200 feet south of jetty, then triangular accretion at jetty.
- F. Composition of Shore: Fine to medium sand. Sand wind sorted.
- G. Protective Structures: Stone jetty (70) at Pamet River entrance, 300 to 400 feet long, 5 foot top width, 1 on 1.5 side slopes, crest stones about 2 tons each with top about 2 feet above mean low water.
- H. Character of Development: Few medium to small summer dwellings.
- I. Damage: Erosion of dunes.

(4) Harbor Bar (North of Pamet River Entrance):

- A. Extent: Approximately 4,000 feet.
- B. Ownership: Public.
- C. Beach Use: Bathing.
- D. Public Facilities: Small parking for estimated 25 cars.
- E. Beach Width Above High Water: Bar ranges from 50 to 60 feet wide except for widening of fillet at Pamet River jetty. Generally about 15 feet from bar to grassed area behind.
- F. Composition of Shore: Medium to coarse sand with small amount of fine gravel. Steep face, approximately 1 on 10 to 1 on 12. Below low water is gravel with sand beneath.
- G. Protective Structures: Stone jetty (71) 250 to 300 feet long at Pamet River entrance. Characteristics about as south jetty.
- H. Character of Development: Undeveloped except for 8 rental cottages of landward side of road.
- I. Damage: None evident, but beach apparently eroding.

(5) Corn Hill Area:

- A. Extent: Approximately 3,000 feet.
- B. Ownership: Private except street end at Great Hollow Road about 250 feet wide.
- C. Beach Use: Bathing.
- D. Public Facilities: Small paved parking area at north end.

- E. Beach Width Above High Water: Approximately 100 feet to small dune then about 100 foot width behind dune to sandy till bluff.
- F. Composition of Shore: Medium to coarse, rather uniform sand.
- G. Protective Structures: None.
- H. Character of Development: Medium to large summer residences.
- I. Damage: None evident though beach is coarse and steep.

(6) Corn Hill to Pond Village:

- A. Extent: Approximately 8,000 feet.
- B. Ownership: Private.
- C. Beach Use: Resident bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: About 100 feet at south narrowing to about 25 feet at north.
- F. Composition of Shore: Coarse sand with small amount of fine gravel, and at south end of reach there is cobble at change in profile and boulders in the nearshore.
- G. Protective Structures: Remains of an old bulkhead of timber piling driven adjacent to each other. The remains extend about 1,200 to 1,500 feet. Structure not effective in present condition.
- H. Character of Development: Scattered medium summer dwellings. Small fish cannery at north end.
- I. Damage: Some erosion of the protective dune. Near center of reach there is some erosion of toe of bluff, but no damage to bluff face.

(7) Pond Village to Pilgrim Beach:

- A. Extent: Approximately 3,500 feet.
- B. Ownership: Private.
- C. Beach Use: Resident bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 50 to 75 feet to bluff.
- F. Composition of Shore: Coarse sand with small gravel and fine sand at dune which runs along toe of bluff.
- G. Protective Structures: None.
- H. Character of Development: Scattered medium size homes.
- I. Damage: Erosion of dune.

(8) Pilgrim Beach:

- A. Extent: Approximately 11,000 feet.
- B. Ownership: Private except 40 feet at Beach Point and 240 feet at old High Head Road.
- C. Beach Use: Bathing.
- D. Public Facilities: Limited parking at Beach Point.
- E. Beach Width Above High Water: Generally 25 to 50 feet.

- F. Composition of Shore: Coarse sand with small amount of gravel. Seaweed on beach.
- G. Protective Structures: 4 low stone groins (72-75) each about 100 feet long which appear to be private construction. The southerly groin is ineffective since stones have unraveled and are scattered. The remaining three are in fair condition and have accumulated material on their southerly sides.
- H. Character of Development: The area is densely populated by motels and rental cottages with a few summer homes interspersed. This appears to be a valuable commercial area.
- I. Damage: No visual evidence of damage but structures are constructed very close to beach berm and would probably be damaged by severe storms.

(9) Pilgrim Beach, North End (Truro & Provincetown):

- A. Extent: Approximately 4,500 feet.
- B. Ownership: Private except for 200 feet at northerly end.
- C. Beach Use: Bathing.
- D. Public Facilities: None.
- E. Beach Width Above High Water: About 25 feet to wide grass flat.
- F. Composition of Shore: Coarse Sand.
- G. Protective Structures: None.
- H. Character of Development: Rental cottages.
- I. Damage: None visible.

i. Town of Provincetown

(1) Provincetown Harbor:

From the end of reach 9 above to about 2,000 feet northward the shore consists of stone revetment with Highway 6 adjacent. From that point northward to the dike there are houses then harbor development with no bathing beach area. There are apparently no serious erosion problems.

(2) Provincetown (New) Beach:

- A. Extent: Approximately 5,500 feet in developed area, frontage to north and to south of beach publicly owned.
- B. Ownership: Public (State).
- C. Beach Use: Bathing.
- D. Public Facilities: Bathhouse, paved parking areas, snack bar, waste receptacles and other facilities.
- E. Beach Width Above High Water: 150 feet at northwest end and 50 feet at southeast end.

- F. Composition of Shore: Medium to coarse sand. At north end there is a flat berm at about 4 to 5 feet above mean low water then a steep seaward slope of approximately 1 on 10. At the south there is narrow berm at about road level then steep slope (say 1 on 10) to about 1 foot above mean high water then about 1 on 40 slope to slightly below mean high water.
- G. Protective Structures: Bituminous revetment (80) with side slope of about 1 on 1 from road level to beach in good condition. 4 stone groins (76-79) each about 100 feet long with landward ends covered with sand and seaward ends damaged. Groins in fair to good condition except northerly groin which is damaged to point of ineffectiveness.
- H. Character of Development: Good state-owned bathing facility.
- I. Damage: None visible at northerly end. At southerly end south of bathhouse old highway pavement now used as walkway is being undermined.

(3) Long Point:

- A. Extent: Approximately 4 miles, extending southerly from Provincetown Beach.
- B. Ownership: Public.
- C. Beach Use: Limited recreation.
- D. Public Facilities: None.
- E. Beach Width Above High Water: 10 to 100 feet to dunes.
- F. Composition of Shore: Fine sand with overlay of gravel. Beach very flat above high water to dune. Steep slope seaward of mid-tide elevation.
- G. Protective Structures: Groin at Long Point Lighthouse constructed of dumped granite, about 200 feet long with top elevation about 4 feet above mean high water.
- H. Character of Development: None.
- I. Damage: Cutting of dune behind beach. According to local people the seaward end of point has lengthened about 250 feet during last 3 years.

APPENDIX B

LITTORAL FORCES

1. Tides. - Tides in the study area are semidiurnal. Mean and spring ranges in the study area vary from 8.7 and 10.1 feet, respectively, at the Cape Cod Canal entrance to 10.0 and 11.6 feet, respectively, at Wellfleet Harbor. Tide ranges along the shore are considered directly proportional to that at Boston and are modified by coastal topography and hydrography. Elevations given herein are referred to the plane of mean low water unless otherwise specified.

2. The nearest station to the study area, for which the United States Coast and Geodetic Survey tidal observations over a long period of time are available, is located at Commonwealth Pier No. 5 in Boston Harbor. The mean and spring ranges of tide at this station are 9.5 and 11.0 feet, respectively. Inspection of 30.3 years of record, covering the period August 1921 to March 1952 (excluding the period January - April 1945), reveals that the highest tide of record was 13.8 feet and occurred only once during the period. These statistics are of tide heights which actually occurred and therefore include tides which were increased by other forces to elevations above that caused by lunar and solar attraction. Table B-1 shows the number of occurrences of tides exceeding the plane of mean high water in increments of one-tenth foot.

TABLE B-1

Boston Harbor, Massachusetts - Number of Tides Exceeding Mean High Water during 30 - 1/3 year Period August 1921 - March 1952.

<u>Feet Above MHW</u>	<u>Number of Occurences (Accumulative)</u>	<u>Average Number of Occurences Per Year</u>
4.3	1	0.03
4.2	2	0.06
4.1	2	0.06
4.0	2	0.06
3.9	2	0.06
3.8	2	0.06
3.7	3	0.1
3.6	4	0.1
3.5	5	0.2
3.4	7	0.2
3.3	11	0.5
3.2	21	0.7
3.1	32	1.1
3.0	44	1.5
2.9	67	2.2
2.8	83	2.7
2.7	110	3.6
2.6	144	4.8

TABLE B-1 (Continued)

<u>Feet Above MHW</u>	<u>Number of Occurrences</u>	<u>Average Number of Occurrences Per Year</u>
2.5	205	6.8
2.4	277	9.1
2.3	358	11.8
2.2	463	15.3
2.1	560	18.5
2.0	741	24.5

3. Differences in tide heights at various points along the coast have been determined by the United States Coast and Geodetic Survey by means of relatively short term periods of observation and related to Boston heights for convenience in predicting tide heights at these locations. These tide differences and heights are shown in Table B-2. The locations of these areas are shown on Plate 1.

4. Storm Tides. - High velocity winds increase tides in varying amounts depending upon direction, duration and severity of the winds, the hydrography of the nearshore and the shelter of the location. The tides, of course, raise the elevation of the water surface so that the waves may cause greater damage to the shore. Table B-3 shows maximum elevations recorded at Boston during recent storms. Table B-4 gives elevations of record prior to 1933. Elevations shown for storms prior to March 1931 were observed at points other than Commonwealth Pier and are therefore not directly comparable to the more recent observations.

TABLE B - 3
RECENT BOSTON STORM TIDES

<u>Date</u>	<u>Elevation in Feet</u>		<u>Height Above Predicted, in Ft.</u>	<u>Height Above MHW, in Ft.</u>
	<u>Observed</u>	<u>Predicted</u>		
1/28/33	13.5	10.3	3.2	4.0
9/21/38	11.3	10.6	0.7	1.8
4/21/40	13.8	11.7	2.1	4.3
11/20/45	12.8	12.0	0.8	3.3
11/22/45	12.7	11.6	1.1	3.2
11/30/45	12.5	8.9	3.6	3.0
8/31/54	13.1	9.9	3.2	3.6
9/11/54	11.0	9.6	1.4	1.5

TABLE B - 2

TIDAL DIFFERENCES AND RANGES

<u>Location</u>	<u>Position</u>		<u>Differences from Boston Tides</u>						<u>Distance* from Boston in Miles</u>
	<u>Lat.</u>	<u>Long.</u>	<u>Time in Hours</u>		<u>Ht. in Feet</u>		<u>Range in Feet</u>		
			<u>High</u>	<u>Low</u>	<u>High</u>	<u>Low</u>	<u>Mean</u>	<u>Spring</u>	
Boston	42°21'	71°03'					9.5	11.0	
Cape Cod Canal Entrance	41°46'	70°30'	-0.01	-0.03	-0.8	0.0	8.7	10.1	47
Barnstable Hbr.	41°43'	70°17'	+0.15	+0.5	0.0	0.0	9.5	11.0	59
Wellfleet	41°56'	70°02'	+0.2	+0.5	+0.5	0.0	10.0	11.6	58
Provincetown	42°03'	70°11'	+0.23	+0.27	-0.4	0.0	9.1	10.6	48
Race Point	42°04'	70°15'	-0.05	-0.07	-0.5	0.0	9.0	10.4	45

* Straight line distance from Boston Harbor.

TABLE B - 4

Boston Storm Tides - Prior to 1933

<u>Date</u>	<u>Elevation</u>
3/4/1931	13.7
12/26/1909	14.8
1/25/1905	13.8
11/3/1861	13.6
12/3/1854	13.7
12/29/1853	13.8
4/16/1851	15.0
3/18/1851	13.9

5. Prevailing Winds. - United States Weather Bureau wind records for Boston, Massachusetts, the weather station located nearest to the study area, for the period October 1949 through September 1958 were used in this study. These data consist of hourly observations of wind speed and direction based on sixteen points of the compass. A wind rose made from these records is shown on Plate 1.

6. The wind rose indicates a preponderance of westerly winds with the greatest duration from the southwest. However, by combining winds within the quadrants it is shown that prevailing winds are from the northwest quadrant. A tabulation of wind data for the Boston station is given in Table B-5.

7. Waves. - No wave observations have been made along the coast, in the study area. The wave characteristics discussed herein were obtained by hindcast methods and are presented in Beach Erosion Board Technical Memorandum No. 55, entitled "North Atlantic Coast Wave Statistics Hindcast by Bretschneider - Revised Sverdrup-Munk Method." The coast of the study area is exposed to deep water waves which are generated by winds from the northerly quadrants. From the directions of north to northwest the fetch is limited by Boston Harbor, and Cape Cod limits the fetch for winds from the easterly direction. A wave rose prepared from hindcast data is included on Plate 1.

8. Hindcasts have been made for a station in deep water off Nauset Beach, Cape Cod, Massachusetts, about 70 miles east-southeast of the center of the study area (see Plate 1 for location). From the wave rose it may be seen that the predominant direction of approach is from the east and east-northeast directions.

9. Storms. - Hurricanes can be defined as tropical cyclones with a central barometric pressure of 29.0 inches or less and winds near the center 75 miles per hour or more in some points in the path. In the northern hemisphere they are known to consist of winds revolving in a counter-clockwise direction about a calm center or "eye". This calm center has an average diameter of approximately 14 miles. The dia-

TABLE B - 5

WIND DATA, BOSTON, MASSACHUSETTS
October 1949 - September 1957

Direction	Speed in Miles per Hour										% Total Duration	Avg. Annual Speed MPH	Wind Movement in Miles	% Total Movement
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	Over 47	Total				
N	73	485	1341	1052	328	112	15	2	-	3408	4.9	12.7	43,292	4.6
NNE	56	323	775	675	336	145	29	5	1	2345	3.3	13.9	32,635	3.4
NE	72	428	878	905	483	217	84	32	11	3110	4.5	15.0	46,549	4.9
ENE	75	331	687	763	354	169	51	16	4	2450	3.5	14.0	35,637	3.7
E	69	386	1119	1105	286	98	35	19	2	3119	4.5	13.3	41,570	4.4
ESE	69	473	1295	1170	215	64	11	-	4	3301	4.7	12.4	40,790	4.3
SE	76	494	1085	751	114	17	-	-	1	2538	3.6	11.2	28,299	2.9
SSE	49	451	894	426	70	22	3	2	1	1918	2.8	10.7	20,458	2.2
S	60	690	1353	893	243	57	10	3	-	3309	4.7	11.7	38,555	4.1
SSW	55	621	1703	1705	649	205	45	15	3	5001	7.1	13.8	69,012	7.3
SW	64	839	3549	3659	1020	245	32	3	-	9411	13.4	13.5	126,953	13.4
WSW	49	483	1660	1645	430	92	15	1	-	4375	6.2	13.1	57,116	6.0
W	60	581	1830	1904	792	254	69	6	-	5496	7.9	14.6	80,202	8.5
WNW	58	808	2623	2769	1244	470	65	11	-	8048	11.5	14.5	116,329	12.3
NW	69	650	2019	2657	1290	518	84	7	4	7298	10.4	15.2	110,729	11.6
NNW	49	461	1511	1631	663	166	18	2	-	4501	6.3	13.5	60,618	6.4
Calms										500	0.7			
TOTALS										70,128	100.0	13.5	948,744	100.0

meter of hurricanes varies considerably, some being 50 to 75 miles; the majority greater, in many instances exceeding 500 miles. Winds at the outer limits are usually light increasing to moderate and gusty toward the center, and they blow with great fury adjacent to the "eye". Hurricanes move bodily along a path in a motion of translation with speeds up to 60 knots. The greatest damage to shore areas caused by these tropical cyclones is the inundation which usually accompanies them. This is especially true where there is a bay to the right of the point where the hurricane center moves inland. The 14-foot rise of water in Narragansett Bay, Rhode Island, during the hurricane of September 1938, which moved inland west of this bay is an example of the devastating effect which such a condition can engender. The strong currents created by hurricanes is an important factor in the destruction caused by such storms. Only a few hurricanes which have passed through the New England area are known to have caused considerable destruction. Ivan Ray Tannehill, in his book "Hurricanes", mentions ten which occurred between 1635 and 1944. Recent hurricanes occurred on September 21, 1938, September 14-15, 1944, August 31, 1954 and September 11, 1954. These hurricanes caused damage throughout New England including coastal damage. However, along the shore of North Cape Cod the coastal damage caused by hurricanes has been less than the damage caused by the more frequent severe northeast storms. Two of these storms are described briefly in the ensuing two paragraphs.

10. Northeast Storm of April 20-22, 1940. - The northern coast of New England was lashed by a northeast gale, accompanied by the highest tide since 1851, on April 20-22, 1940. The storm center moved slowly along the coast from a point in eastern Kentucky on the 20th, to a point north of Portland, Maine on the 22nd. The storm reached Boston, Massachusetts at about 4:00 P.M. on the 20th and lasted until about 11:00 P.M. on the 21st. The storm, coming at the time of spring tides, built up the normally high tides to extreme tides which continued through the 22nd. Extreme tide recorded at Commonwealth Pier in Boston was 13.8 feet above mean low water. Heavy surf pounded the coast during the gale and spray was reported to have dashed over the 110-foot tower at Minot's Light off Scituate and to have carried 25 feet above the 105-foot cliff on Deer Island in Boston Harbor. During the period of 31 hours, there was a wind velocity of 30 or more miles per hour at the East Boston Airport. The extreme instantaneous velocity recorded was 49 miles per hour. Before and after that of gale force, the wind was from the north, but during the gale the wind was from northeast. Damage occurred throughout the study area with principal coastal damage consisting of erosion of beaches and cliffs; destruction of sea walls and bulkheads; undermining of highways and buildings, several of which were demolished; and, the flooding of low lands, buildings and roads.

11. Northeast Storm of November 28-30, 1945. - This storm was the last of three severe storms attacking New England during the ten-day period of November 20-30. The first two storms, occurring on November 20 and 22, affected principally the states of New Hampshire and Maine. Damage within the study area was negligible. The storm damaging the study area was a three-day northeast storm occurring on November 29 to 30 inclusive, with high winds continuing through December 1. Its greatest intensity was about 53 hours in duration centering around Boston and Cape Cod. The storm was a typical northeaster which gained in intensity for three successive days, building up to maximum wave action and tidal heights which resulted in severe coastal damage. At Boston the wind attained a maximum velocity for a five minute period of 63 miles per hour and an extreme velocity for a one minute period of 68 miles per hour. A maximum velocity of 110 miles per hour was observed at Mount Washington Observatory, New Hampshire. The predicted tides at Boston for the three-day period ranged from 8.4 to 8.9 feet above mean low water and the actual recorded tides ranged from 9.1 to 12.5 feet. Coastal damage was severe throughout the study area. However, had the storm occurred during a period of spring tide ranges rather than during neap tides, as occurred, the damage would probably have been greater.

12. Storm Winds. - A diagram showing distribution of winds over 32 miles per hour circumscribe the wind rose shown on Plate 1. These data are also from records of the United States Weather Bureau and cover the period October 1949 through September 1957. The diagram shows a predominance of storm winds from the northeast.

13. A summary of wind speed, direction, duration and total movement is given in Table B-5. The summary shows the winds which have occurred in recent years. However, it is considered that the seven year period is too short to provide a reliable measure of wind frequency. This record is in general agreement with the 75 year record of gales occurring in Boston (see following paragraph 14) in that it shows a predominance of winds of speed of 39 miles per hour or greater occurring from the northeast. It is therefore indicated that a high predominance of the severe storms occurring at Boston, and therefore probably in the study area, approach the shore from the northeast.

14. A summary of the number of gales (continuous winds with velocities over 32 miles per hour) occurring at Boston during the 75 year period 1870-1945 as compiled from records of the Weather Bureau are shown below:

Gales (1870-1945)

Direction	N	NE	E	SE	S	SW	W	NW	TOTAL
No. of Gales	3	80	9	14	12	15	13	14	160
Percent of Total	2	50	6	9	7	9	8	9	100

Classification of direction of each gale was made in accordance with the predominant direction of wind. Variations in direction during gales are not accounted for. This tabulation also indicates a high preponderance of severe northeast gales.

15. Storm Damages. - A condensed account of storm damages within the study area was compiled from damage reports and newspaper clippings. This compilation was not confined to beach or shore property damages but includes the general types of damages resulting from wave action. The data are presented below by date of storm event.

a. February, 1940. - Two storms occurred on the 14th and 19th of February. Severe damage at Spring Hill Beach, Sandwich consisting of erosion of the dune, undermining of 7 cottages on the dune and shoaling of the mouth of Sandwich Harbor.

b. April, 1940. - A 3-day northeast storm occurring April 20-22 eroded the bluff at Spring Hill Beach, Sandwich causing a 10 to 25-foot retreat. About 25 cottages were damaged. Total estimated damage was about \$3,000.

c. September, 1944. - A hurricane occurred on September 14 and 15. Minor damage to buildings at Spring Hill Beach, Sandwich. At Provincetown the Cape Cod Cold Storage pier was severely damaged, damage to boats estimated in excess of \$300,000, fishing equipment and fish weirs damaged to extent that fishing activities could not be accomplished during remainder of year.

d. November, 1945. - (1) At Spring Hill Beach about one mile long section of dune was cut back about an average of 15 feet, undermining 13 cottages and damaging riprap.

(2) Provincetown, east end: - Beach levels were reduced about three feet. Concrete caps on seawalls and wood bulkheads were destroyed and backfill eroded causing damage to cottages, walks, streets and riprap protection.

(3) Provincetown, center - Concrete walls and bulkheads damaged, sand dunes eroded 3 to 4 feet landward, small craft damaged, highways obstructed by water and debris and a 60-foot long navy boat sunk at pier.

(4) Provincetown, west end. - About 125 feet of the Federal breakwater settled 4 to 6 feet. Concrete seawalls and bulkheads damaged and backfill eroded, beach lowered 1.5 to 2 feet, dune retreated about 4 feet, two boats destroyed and others damaged.

e. November, 1947. - (1) Storm on 12 November caused flooding in Provincetown on Commercial and Main Streets to Town Hall lawn. Other streets inundated and docks and boats were destroyed. Damage to shore and harbor in Provincetown estimated to be over \$100,000.

(2) Extensive flood damage to roads and shore property reported in Yarmouth.

f. September, 1950. - (1) A hurricane occurring on September 12 disrupted communications and power throughout Cape Cod. Several deaths were attributed to the storm, many boats were destroyed and highways damaged. Highway damage was estimated to be about \$250,000 and loss of fishing equipment was estimated at \$150,000.

(2) In Sandwich power was disrupted, roads flooded, boats damaged, beach property damaged and schools were closed.

(3) In Brewster power was disrupted, roads were flooded and schools were closed.

(4) In Provincetown many boats were destroyed and others damaged.

g. November, 1950. - Storm on November 25-27 damaged fishing and lobster industry.

h. November, 1953. - A storm on November 6 and 7 caused inundation of roads at various locations throughout the Cape. Other damage consisted of interruption of electrical power and damage to docks, piers, boats and fishing gear. In Provincetown there was damage to fishing equipment, boats and docks, as well as minor shore erosion and seawall damage, estimated at \$60,000.

i. August - September, 1954. - Hurricanes occurred on August 31 and September 11, 1954 causing damage throughout New England.

(1) At Yarmouth about 100 feet of South Shore drive was damaged, boats were damaged and several piers were destroyed. Damage was estimated to be about \$50,000.

(2) At Dennis shore front property damaged by wave action, cottages and tents were swept from foundations, and residents were evacuated from some areas.

(3) At Provincetown damage to shore front property, public utilities, boats and fishing equipment was estimated to be about \$150,000.

APPENDIX C

LITTORAL DRIFT AND GENERAL EROSION DATA

1. General. - This appendix provides information on existing evidence of the movement of littoral drift and conclusions and observations made in the past by various students of the Cape Cod shore.

2. Littoral Drift. - Conclusions regarding the predominant direction of littoral drift throughout the study area has been made by accretion at structures as observed during the detailed inspection made on May 12-14, 1958, August 12-13, 1958, August 19-20, 1958 and August 28, 1959. Additional evidence was obtained by analysis of the shore line change maps, plates 11 to 20. In general it appears that the predominant direction of drift is as follows: west to east from Cape Cod Canal to Barnstable Harbor; east to west throughout the Town of Dennis; west to east then northward from the Town of Brewster to Wellfleet Harbor; northward in the Town of Truro; and along the westerly face of the outer end of the cape, southward from Race Pt. toward the outer end of Long Pt.

3. Evidence obtained from the detailed inspection and from shore line change maps is listed below:

- a. Accretion on the northwest side of groins about 1000 feet eastward of Cape Cod Canal.
- b. Accretion on westerly side of groins along Town Neck and at northwesterly jetties of Sandwich Harbor and Scorton Harbor.
- c. Erosion east of Sandwich Harbor and Scorton Harbor.
- d. Slight accretion westerly of groin (10), 2000 feet southeasterly of Sandwich Harbor.
- e. Enlargement of Beach Point, Sandy Neck.
- f. Accretion easterly of groins 1,000 feet west of Nobscusset Point.
- g. Accretion east of groins at Nobscusset Point.
- h. Slight accretion on east side of groin at Dennis Town Beach.

- i. Accretion on east side of groins east of Sesuit Harbor and at Sesuit Harbor east jetty.
- j. Accretion west of groins throughout the Town of Brewster.
- k. Small accretion at Pamet River south jetty.
- l. Accretion on south side of groins at Pilgrim Beach.
- m. Accretion on north side of groins along Provincetown (New) Beach.
- n. Apparent movement by storms of material toward outer end of Long Point.

4. Erosion on Cape Cod. - The following are notes from various texts and papers regarding shore processes on the Cape.

Erosion on the east coast and the growth of the Cape into Mass. Bay was noted by Hitchcock in 1841.

Swamp peat from the inner side of bars appears on exposed beaches as noted by Thoreau in 1855.

H. L. Whiting (USC and GS) concluded in 1878 that Provinceland consists of "sea sand" supplied by erosion on the east side of the Cape.

K. Weule, in 1891, confirmed the belief expressed earlier by Louis Agassiz that the Cape is preserved by sand brought from shoals on the southeast by flood tide, concluding that the existing mainland is only a remnant of a great extent of drift land.

W. M. Davis, in 1896, published a theory of the mechanics involved in the development of the Cape and bars, describing a series of concentric "wing" bars dating from oldest (now fossil) bars at North Truro, to most recent, representing outer Provincetown. The process was summarized by Woodward in 1934 as follows:

"As the coast of the ocean or 'back' side of the Cape retreated under the action of the sea and straightened out, the flying beach would spring off from the head of the Cape and the sandy hook beyond the point of contact with the coast would grow outward, thus the oldest part of the hook at Provincetown is on the inside next to the harbor and the newer part on the north."

Davis stated that the swinging of the shore current on its

'movable fulchrum' has as another consequence the "rapid consumption of the bar that extends from Race Point inlet to Wood End, the long 'finger' at the end of the Cape." He adds that the bar form is preserved by "the continued feeding, from the cliffs and from the bottom off shore, by which the volume of the bars is sustained." He attributed the growth of Long Point to undernourishment of the bar from Race Point inlet to Woods End, the sand taken from it by northwest gales. Long Point, like Race Point, he states, has advanced into comparatively deep water, adding that the 20-fathom curve was only 600' off shore, and pointing out that the same depth was not found for almost 3 miles off the cliffed shore of the 'back' of the Cape.

Woodworth concluded that the Provincetown "Wing-bar" has undergone little change since it was first mapped, stating, "in 1857 Whiting found by comparing late maps with those made by the survey of 1849, that the changes were most pronounced near Race Point and East Harbor. Lance's Harbor had been closed, and the enclosing beach for 2-1/2 to 3 miles between Race Point and Long Point, forming the finger of the Cape, had been driven in from 100 to 300 feet. In 1849 the beach between East Harbor and the ocean was about 300 feet wide where narrowest and about 40 feet high. In 1857 Mitchell found the beach at this place about 100 feet wide and 12-15 feet high. He records a report that the sea had broken over this place in the preceding winter. Certain small scale maps that form illustrations in books published at the end of the 18th century show a passage through the outer beach at the west end of East Harbor (Pilgrim Lake on recent charts), seeming to indicate that for a time after the survey by DesBarres the sea broke through the bar at this place; but no authentic record has been found. Any such eruption, however disastrous it might have been for Provincetown Harbor, would have soon been closed by the long-shore transportation of sand from the cliffs of Truro and Wellfleet.

"In 1868-9 a dike was built at the 'wading place' at High Head (on Pilgrim Heights) by the United States, and another dike was built to close the connection between East Harbor and the bay, thus converting the East Harbor into Pilgrim Lake. In 1870 a dike was built at the head of Lancy's Harbor, at the foot of Abel Hill, to prevent the flow of tide from Lancy's Harbor into Provincetown Harbor. More recently a dike has been built from Steven's Point across the House Point Island Flats to Long Point, formerly there was a small inlet on these Flats, known as House Point Island, which has gradually disappeared. In 1890 Marinden found Lancy's Harbor a 'dry sand and gravel slough'".

Davis, in 1896, concluded that the western shore of the Cape has suffered a total recession of not more than 3,000 feet,

"accomplished chiefly by northwest gales and north to south shore currents, by which the waste gathered from the more continuously cliffed shore was carried southward to tie together the several islands below South Truro." He observes that northwest gales are not dominant anymore, having been replaced by weaker southwest gales. Referring to the Provinceland area he concludes, "the only part of the northeast shore that is liable to be broken through lies on the stretch between the point where the connecting bar springs northwest from the great cliff and the point where the 'Fulchrum' is at present located. Within this stretch, the bar is generally retreating, being out on the outer side and reconstructed on the inner side." He recommended safeguards to, "cause the Fulchrum to migrate southeastward, therefore diminish the length of the thin bar, and increase its breadth and strength." This would be by, "the construction of bulkheads along the outside of the narrow bar, or wrist, so as to catch the body of a shipwrecked vessel causes an accumulation of sand on its southeast side, a significant addition to the narrow bar might soon be made The bulkheads should be continually built out so always to project a little beyond the aggrading shoreline. The fear that, in case the narrow connecting bar or 'wrist' should be breached, the whole action of the Atlantic longshore currents would thereafter be directed through the breach into Provincetown Harbor, is groundless." The "whole history" of the area, he points out, indicates that "the longshore currents must continue to swing in long curves of large radius in the future, as in the past. The danger of silting Provincetown Harbor by drift from the west concave shoreline along the west protecting bar of High Head does not appear to be imminent, for the processes of transportation are comparatively slow on the inner side of the Cape; but the danger is nevertheless real, and nothing but an extensive and expensive system of bulkheads from North Truro northward appears to be sufficient to avert it. The destruction of the narrow strip of sand bar shore between Race Point and the Wood End seems to me to threaten Provincetown Harbor with a greater danger than any that it is exposed to from the east. This shore is now wasting rapidly. Once broken through the currents driven by northwest gales, as well as by the rising tide, would no longer have to swing around Wood End and deliver their load of drifting sand to Long Point; they would in all probability invade the harbor directly, cutting away the low-tide flats that now expand south of the village, and throwing the detritus thus gained into the harbor." Davis also notes that the rate of consumption of the Truro mainland north of Orleans was 3.2 ft./year. "It does not seem at all likely that, while the rest of the Truro mainland is wearing away, the spit at Race Point will of itself curve around to the south, and thus save from destruction the narrowing bar which encloses Provincetown Harbor on the west. A great volume of transported sand would be needed to continue the bar in the deep water through which its

present curve would lead. Moreover, the shoal known as Peaked Hill bar may, as has been suggested, mark the beginning of a shoreline exterior to that of the present Race Point curve. It is possible that as additional tangent spits are lapped on the outside of the curve, Race Point will be cut back by a current from the northwest, working opposite to the great current that rounds the peninsula from the east, a cusped or acuminate spit being then formed in the angle between the two, such as now exists at Great Point, Nantucket. The Provincetown peninsula may be expected to outlast the Truro mainland; for as long as the latter exists, the former now receive contributions from it."

"In the Coast Survey Report of 1867, Whiting states that, between Graham's survey in 1835 and his re-survey in 1867, Long Point had become extended above high water as much as 2,460 feet. The flats between Long Point and the western part of the village advanced in the same period (32 years) an average distance of 275 feet upon the harbor. Beach Point, which was built out from the west side of High Head, advanced in the same period 1,000 feet on the south side of East Harbor, but the main shore of the inlet opposite the point had receded 200 feet. At the same time the bar had moved inward about 200 feet. On the ocean side of the harbor Whiting found the bar still more reduced in width and height than it was in Mitchell's survey, and he recommended that the East Harbor be closed.

"In 1890 Marinden found that the outer beach back of East Harbor had come in still farther since the survey of 1867, so that the width of the barrier there had been reduced; also that although the harbor opposite the town showed scouring and deepening, the mud flats between Stevens Point and Long Point had advanced somewhat into the harbor.

"The surveys of Monomy and Provincetown Harbor showed that much more material is being transported southward along the Cape to the sand bars of Chatham and Monomy than northward to Provincetown because of the greater force of the northeast storms. Moreover, Cape Cod is fended on the southeast by great shoals from the full force of the waves. During a northeaster the Provincetown spit is driven in from the ocean side, hence the bar that ends in Long Point". "The drift of sand toward the Provincetown bar being thus increased, if it should counterbalance the loss from the decrease in thickness of the deposits above sea level as the coast recedes, would tend to establish stability and to preserve Provincetown Harbor, at least in outline."

"On the inside of the arm of the Cape there are a number of islands and offshore bars that end on the south in Billingsgate

Island. On DesBarres' chart (1780) no barrier beach is shown between the land at South Truro and Bound Brook Island, nor between Griffin Island and Great Island, and Great Island and Great Beach Hill Island, such as is shown on the chart of 1887. It is said that the barrier beach once continued southward to Billingsgate Island, and beyond it to the little remnant hook island further south, on which Billingsgate Light House stood in the 70's, when a remnant of this barrier beach formed a small island between Beach Hill Island and Billingsgate Island. In recent years much of the northern part of Billingsgate Island has been washed away.¹⁰¹

¹⁰²Barnstable Harbor, on the south shore of Cape Cod Bay, is guarded on the north by a long barrier beach that is built eastward along the curving shore where the sea beats against drift hills back of the frontal moraine, such as Scorton Neck, to which the beach is an appendage. "A detailed chart of Barnstable Harbor, on a scale of 1:20,000, was prepared in 1861 by Henry Mitchell and published in the U. S. Coast Survey Report for that year. The beach known as 'Sandy Neck' has undergone few changes since this survey was made. It is said that since the breakwater at the entrance to the Cape Cod Canal was built the beach along this shore has begun to wash away. If this statement is true the change has probably occurred because the longshore drift from the high cliffs on the west side of the bay no longer reaches the barrier beaches east of the canal and must therefore be deposited near the breakwaters of the canal."¹⁰³ Woodworth notes that during Minot Gale of 1851 and the storm of November, 1898, "the sea rose some 18 feet above its normal level in Barnstable."¹⁰⁴

¹⁰⁵If we plot the direction of the longshore drift against the chief tangent bars and winged beaches of the Cape and Bay inside it, it will become obvious that wash from the shores of the Bay become pocketed except where tidal scour carries them out upon the bottom, and that the headland of the Cape is being driven inward by a general southward movement of the coastal waste."¹⁰⁶

Notes on Wind Action (Woodworth)

¹⁰⁷The geological action of the wind on Cape Cod consists of the deflation of the glacial gravel of the upland, the erosion of the the cliffs, and the formation of dunes along the beaches.

¹⁰⁸The 'blewholes' of lag-gravel tracts and the windswept face of the cliff at Highland Light afford an excellent field for observing the action of wind on glacial material. The prevailing wind blows from the southwest, and as it is fairly dry it probably does most of the cutting. The winds from the north, northeast, east, southeast, and south are usually damp, and the moisture they form causes the grains of sand to resist them so that only a strong wind from these quarters can move the sand.

"The sand and dust blown from the lag-gravel tracts of the glacial drift form conspicuous deposits only near the edges of cliffs, where the work of the wind is reinforced by the vertical movements there set up. High dunes are formed in such positions, and nowhere more abundant in this region than in the stretch on the outside of Cape Cod between Highland Light and Nauset Light, just where the cliffs are highest and steepest. A belt of such dunes and associated tracts of lag-gravel border the top of the cliffs in Wellfleet and Truro for a considerable distance north and south of the Pamet River Coast Guard Station at elevations as high as 100 feet above sea level where the older glacial gravel attains this level."

"The principal dunes of the Cape Cod peninsula are formed by the inshore wind on the great flying beaches at the north and south ends of the headland that is, at Provincetown, Monomoy and along the Barnstable Beach. Many other small dunes are found on the shore of the open sea, along the sound on the south and along the shore of the bay where the beaches furnish the sand." Dunes at Provincetown have been recorded as high as elevation 100 feet - (the great ridge) by the McClintock survey of 1892. "By comparing the present position of the dune ridge with its position of the dune ridge with its position as shown on Graham's chart McClintock concluded that the ridge had steadily moved inward from the ocean toward the harbor at a rate of about 10 feet/year. 'The north wind,' he writes, 'as a motive power annually carries more than 1,000,000 tons of sand a distance of half a mile from the northern front to the rear of the ridge.' In the same report Mr. H. S. Cook, a native resident, testified that sand is blown in by the north wind but by no other."

Barnstable Dunes

"The flying beach terminating in Sandy Neck . . . is the site of a narrow strip of low dunes. Along its southern somewhat crenulate border this strip shown traces of old stages in the forward building of the hooked end of the eastward - growing spit. Here six or more of these old hooks, now bearing dunes, are distinctly shown. The latest line of dunes, back of the Sandy Neck Light, is separated from the older accumulations by a cove and a strip of marsh."

"Certain minor details in the distribution of small dunes at places along the harbor side of Sandy Neck as, for instance, back of Mussel Point and near the head of Wells Creek - indicate the submergence of dunes since their formation, for the dunes are now surrounded or are confronted at their bases by salt marsh."

APPENDIX D

PROTECTIVE STRUCTURES

1. General. - The following listing of protective structures located along the shore of the study area as of May-August 1958 were obtained from field inspection, plans furnished by the Commonwealth of Massachusetts, permit drawings and aerial photographs. The information is arranged in geographic order beginning at the west limit of the area and proceeding eastward and northward. Numbers in parenthesis following type of structure is the designation number locating that structure on Plates. Elevations are referred to the plane of mean low water unless otherwise specified.

Town of Sandwich

Structure Number

Description

- | | |
|-------|--|
| (1) | Southeast Jetty, Cape Cod Canal - Stone Jetty 600 feet long, project calls for top elevation of 10 feet and side slopes 1 on 1. Fair to poor condition, and lower than project height. |
| (2) | Stone groin at Town Neck Road 200 feet long, top elevation sloping from 14 to 9 feet, top width 5 feet, side slopes 1.5 on 1 with toe stone penetration 1.5 feet minimum. Constructed December 1953. Fair condition, damaged between M.T. and H. W. |
| (3-7) | Stone groins. (3) constructed in June 1956, (4-7) constructed September 1957. Groins 600 feet apart, approximately 200 feet long, top elevation sloping from 16 to 10 feet, side slopes 1.5 on 1 and top width 6 feet. (3) and (4) in good condition, (5) and (6) in fair condition and (7) in bad condition. |
| (8-9) | West and East Jetties at Sandwich Harbor. Present jetties are about 600 feet and 320 feet long. The inner 325 feet of west jetty (8) constructed of concrete with riprap toe protection and outer 275 feet of stone. The inner 308 feet of east jetty (9) constructed of concrete with stone toe protection and outer 20 feet of stone. Available records on the jetties show the following: |

1914 - concrete portions of jetties constructed

Structure
Number

Description

- 1915 - repairs to both jetties, extension of west jetty, riprapped both sides of jetties.
- (10-26) 17 stone groins ranging in length from 175 to 200 feet, top elevation sloping from 16 to 10 feet, top width 6 feet, side slopes 1 on 1.5. Groins (10, 11 and 16-26) in fair to good condition, groins (12-15) in fair to poor condition. Records indicate groins built and repaired as follows:
- 1940 - groins (14, 16 and 17-19) constructed.
- 1941 - groins (12 and 23-26) constructed, groin (14) repaired.
- 1946 - groins (10 and 11) constructed and groin (12) repaired.
- 1956 - groins (20-22) constructed, groins (18, 19, 23-26) reconstructed.
- (27) West Jetty at Scorton Harbor - Jetty 250 feet long, top elevation 12.4 feet, top width 5 feet, side slopes 1 on 1.5. A jetty was constructed in 1907 and repaired at various times. The jetty was reconstructed to its present alignment in 1941 and 1956.
- (28) East Jetty at Scorton Harbor. - The stone jetty was first constructed in 1908 and extended landward in 1911.

Town of Dennis

- (29) Small stone groin at north Dennis Beach. Groin practically destroyed has little effect on beach. Constructed in 1934.
- (30-31) Two stone groins about 480 feet apart with the easterly at Taunton Avenue, East Dennis Beach. Each groin is 190 feet long, top elevation sloping from 16 to 10 feet, top width 6 feet and side slopes of 1 on 1.5. Groins constructed in 1956. Sand fill was placed between the groins. These groins were built easterly of two groins constructed in 1934. The

Structure
Number

westerly groin of 1934 is (29) and the easterly was removed when the present groin (31) was constructed.

(32-33)

Two stone groins 400 feet apart were constructed in 1933. The west groin (32) was constructed 170 feet long and east groin (33) 150 feet long. The groins have a top width of 5 feet and side slopes of 1 on 1.5. Dates of repairs are not available. However, the groins apparently have been rebuilt recently and are now in good condition.

(34)

Nobscusset Harbor breakwater. - The structure now consists of a stone mound along the shore from groin (32) eastward to groin (33) thence a timber pile and sheet structure (34) extends eastward about 350 feet then turns southeast for about 470 feet. The seaward sides of the timber structure are riprapped. The structure was constructed and repaired as follows:

1915 - Timber bulkhead parallel to shore constructed.

1916 - Bulkhead riprapped and extended.

1917 - Added riprap.

1918 - Repaired breakwater.

1919 - Repairs.

1921 - Replaced riprap.

1934 - Replaced riprap along outer side of timber breakwater, top elevation 15 feet, slope 1 on 1. Placed stone mound alongside old timber, shore connection. Mound to elevation 14, side slopes 1 on 1.5. Area inside harbor dredged material and placed on shore southeast of groin (36).

1935 - Added riprap to breakwater.

1951 - Riprap removed and reset from groin (32) to about 100 feet east of groin

Structure
Number

(33). Riprap stone replaced as a stone mound with top elevation of 17 feet, top width of 5 feet, back slope 1 on 1 and face slope of 1 on 2.

1952 - Stone mound between structures (32) and (33) repaired. Top width increased to 8 feet. Structure probably has been repaired since 1952 as is now in good condition.

- (35) Stone revetment about 200 feet in length protecting the paved parking area. The structure is behind the harbor breakwater. There is no historical information available on the structure which is in good condition.
- (36) Stone groin about 100 feet long near east town property line. The time of construction is not known but a map shows groin in place at the time of the harbor dredging in 1934. The groin is low and is in fair to poor condition.
- (37) Stone revetment about 500 feet in length extending westward along the shore from west jetty Sesuit Harbor (38). The revetment protects the small bank paralleling the shore line. The revetment is in good condition. There is no historical information on this structure available at this time.
- (38) West jetty of Sesuit Harbor. - A stone jetty extending about 600 feet in a northeasterly direction then turning and running in a northerly direction for about 100 feet. The outer 100 feet is generally parallel to the east jetty (39). The top of the structure extends to about elevation 11 feet above mean low water, has a top width of about 5 feet and side slopes of about 1 on 1.5. The landward 200 feet of the structure was constructed in 1937. The dates of the additional repairs are unknown. The structure is in good condition. Earlier there was a stone jetty generally parallel to and about 100 feet west of the east jetty. This jetty was apparently removed at the time of the completion of the existing west jetty.

Structure
Number

(39)

East jetty of Sesuit Harbor. - This jetty is about 1600 feet long, aligned generally perpendicular to the shore, and has a top width of 3 feet, top elevation of 11 feet and side slopes of 1 on 1.5. The structure is in good condition. Available historical information is as follows:

1851 - Constructed jetty 1,000 feet long.

1909 - Constructed jetty 630 feet long.

1910 - Extended jetty.

1946 - Jetty repairs, extend inshore end of jetty 100 feet, dredged channel and deposited spoil east of jetty.

(40-42)

Three stone groins spaced about 550, 1,000 and 1,500 feet from the east breakwater at Sesuit Harbor (39). The groins are 165, 153, and 150 feet long, having top widths of 5.0 feet, side slopes of 1.5 on 1 and top elevations sloping from 12 to 9.6 feet. The groins are in good condition.

Town of Brewster

(43)

The stone revetment constructed in 1955 is about 550 feet in length and extends from about the northwest corner of the parking area that is located at the shore end of Paines Creek Road, eastward to the stone groin (44). Records indicate that the structure was built to the following dimensions. Top elevation about 16 feet, which is flush with the top of slope, slope distance of 10 feet, minimum stone penetration of 2 feet at toe of slope. The revetment is in good condition.

(44)

A stone groin (44) constructed in 1955 by the Commonwealth located at the east end of structure (43). The groin is about 150 feet long, has a top elevation sloping from 14 to 9 feet, top width of 5 feet and side slopes of 1.5 on 1. After groin construction sand fill was placed along 300 feet of shore forming a beach 50 feet wide at elevation 14 feet then sloping seaward on a 15 on 1 slope. The sand fill has apparently completely eroded away.

Structure
Number

- (45-52) Eight stone groins ranging in length from 125 to 200 feet, spaced approximately 400 feet apart and located from 2600 feet to 5400 feet east of the entrance to Herring River. The top elevations slope from 14 to 10 feet, top widths 5 feet, side slopes 1.5 on 1. Records indicate that (2) groins were constructed in 1946, (1) in 1951, (2) in 1953 and (3) in 1955.
- (53) A stone revetment (53) about 500 feet long extending easterly from structure (52). The design or historical data on this structure is not available.
- (54-56) Three stone groins (54-56) located in the vicinity of Breakwater Road. The lengths of the groins are 90, 110 and 110 feet, respectively, with top elevations of 10 feet, top widths of 4 feet and side slopes of 1.5 on 1. The groins were constructed in 1957 and are in good condition.
- (57-59) Three stone groins located in the vicinity of Point of Rocks Road were constructed in 1957 and are spaced about 300 feet apart. Their lengths are 187, 198 and 198 feet, respectively. Each groin has a top elevation sloping from 18 to 10 feet, top width of 6 feet, side slopes of 1.5 on 1 and a minimum height of 4 feet. The groins are in good condition.
- (60) A stone groin about 150 feet long located about 1000 feet easterly of groin (59). There is no historical or design information available on the structure. The groin is in good condition.
- (61-62) Stone groin and revetment located at the shore end of Foster Road. The groin has a length of about 160 feet and a stone revetment (62) connected to its inner end that extends eastward about 30 feet. The groin has a top elevation sloping from 14 to 10 feet, top width of 5 feet and side slopes of 1.5 on 1. The stone revetment has a width of about 18 feet, top elevation of 21 feet and a toe elevation of 14 feet. Both the groin and revetment were constructed in 1954 and are in good condition.
- (63) Stone groin about 75 feet long located at the shore end of Linnell's Landing Road was built by the State in 1946. The groin was constructed 140 feet long with a top elevation sloping from 12.5 to 10.5 feet and side slopes of

Structure
Number

1.5 on 1. The groin is in poor condition.

- (64) Stone groin about 150 feet long located about 270 feet east of structure (63) with a top elevation sloping from 17 to 9.5 feet, top width of 5 feet and side slopes of 1.5 on 1. The groin constructed by the State in 1949 is in good condition.

- (65-67) Three stone groins about 200, 195 and 185 feet long, spaced about 800 feet apart. The most westerly groin is located at the shore end of Crosby Lane. Each groin has a top elevation sloping from 18 to 13 feet, top width of 6 feet and side slopes of 1.5 on 1. These groins were constructed in 1957 and are in good condition.

Town of Wellfleet

- (68) Stone breakwater constructed by the State in 1957 at the north end of Indian Neck in Wellfleet Harbor. The structure extends in a northwest direction for about 1000 feet. The inner 500 feet is constructed to a minimum depth of 2 feet below original ground and the outer 500 feet is on original ground. The top elevation for the entire length is 13 feet with a top width of 8 feet, side slopes of 1.5 on 1 at harbor side and 2 on 1 along the seaward side. The condition of the breakwater is good.

- (69) Stone revetment about 800 feet long at the end of Chequesset Road was constructed in 1955 by the Commonwealth of Massachusetts. A paved parking area is located along the revetment. The revetment has a top elevation of 23 feet, side slopes of 1.5 on 1, a minimum toe penetration of 2 feet. The structure is in good condition.

Town of Truro

- (70-71) South (70) and north (71) jetties at the entrance to the Pamet River were reconstructed to their present dimensions in 1950-1951. The jetties are 330 and 300 feet long. The south jetty was constructed of granite blocks with a stone chip core, a top width of 8 feet and a top elevation of 12 feet. The north jetty is constructed of granite blocks with stone chinking, has a top elevation

Structure
Number

of 18 feet and a top width of 5 feet. Both jetties have side slopes of 1.5 on 1 and toe penetration of 1.5 feet. The jetties are in good condition. Construction and repair of the jetties are as follows:

1917 - Sod dike 1600 feet long constructed along north side of entrance.

1919 - Constructed north jetty 175 feet long, south jetty 80 feet long, placed riprap along 300 feet of shore north of north jetty, and 230 feet of riprap south from south jetty.

1924 - Repairs.

1937 - Rebuilt both jetties 200 feet long.

1950-1951 - Reconstruction as described above.

(72-75)

Four stone groins located near the south end of Pilgrim Beach constructed by the Commonwealth. The groins are located near the south limit, about the center, about 1600 feet north and 2500 feet north of Day Camps Motel. The groins were constructed as follows:

(72) Constructed in 1938 about 200 feet long, height of 3 feet, side slopes of 1.5 on 1 and toe stone penetration of 1.5 feet.

(73) Constructed in 1936, height of 3 feet, top width of 4 feet, length of 200 feet and side slopes of 1.5 on 1.

(74) Constructed in 1938, 200 feet long, height of 3 feet, top width of 3 feet, minimum toe stone penetration of 1.5 feet and side slopes of 1.5 on 1.

(75) Constructed in 1937, 200 feet long, height of 3 feet, top width of 3 feet, side slopes of 1.5 on 1 and toe stone penetration of 1.5 feet.

Structure
Number

Town of Provincetown

(76-79)

Four low stone groins about 100 feet long. The inner ends are covered with sand and at the outer ends the stone is disarranged. The most northerly groin is damaged to a point of ineffectiveness. There is no available historical or design data on these groins.

(80)

Bituminous slope revetment on a 1 on 1 slope fronting the paved parking area located north of the State bath-house. There is no historical or design data available on the structure.

APPENDIX E

SHORELINE AND OFFSHORE CHANGES

1. General. - Shore line and offshore change data were furnished in the form of maps by the Beach Erosion Board staff. These data consisted of highwater shore lines for the entire study area and 6, 12, 18, 24 and 30-foot depth contours for a part of the study area. These lines were determined from surveys made by the United States Coast and Geodetic Survey in 1833-35, 1848, 1856-57, 1859-61, 1867, 1889-90, 1909, 1933, 1934, 1938-43 and 1952-55. This information is shown on Plates 11 to 20. These plates also include the high water shore line at the five areas of detail study of this report as determined by survey made in September and October 1958 by the U. S. Army Engineer Division, New England. The highwater shore line changes and the offshore changes are discussed in following paragraphs.

High Water Shore Line Changes

2. Cape Cod Canal to Sandwich Harbor. - The overall change in the position of the high water shore line in this reach during the period 1859 - 1955 has been accretion in the form of fillets at Cape Cod Canal jetty and Sandwich Harbor west jetty, and erosion between these fillets. The maximum erosion occurred about 1,800 feet east of the Cape Cod Canal jetty and amounted to a recession in the line of about 250 feet. The entire shore line, including the fillets has receded since 1940.

3. Sandwich Harbor to Scorton Harbor. - The shore line of this entire reach, except at a section about 3,000 feet long where groins have been built and at Scorton Harbor west jetty where a fillet has formed, receded during the period 1859-1955. Maximum erosion occurred about 1,500 feet east of Sandwich Harbor where the shore receded about 350 feet.

4. Scorton Harbor to Beach Point (Sandy Neck). - During the period 1859 to 1952 erosion of up to 170 feet occurred to about 9000 feet east of Scorton Harbor, then mixed erosion and accretion with overall effect of erosion occurred for the following 15,000 feet, thence erosion up to 200 feet to within 5000 feet of Beach Point, then accretion at the Point. Beach Point extended eastward about 400 feet between 1859 and 1912 then an additional 600 feet between 1912 and 1955. Therefore, the spit extended eastward over 10 feet per year for 96 years.

5. Bass Hole to Nobscusset Harbor. - The southwesterly 2000 feet of the reach, at Bass Hole, had many different shapes between 1859 and 1955 growing to the barrier beach shape it now possesses. From this

point for an additional 2,500 feet there was accretion ranging from 400 to 600 feet between 1859 and 1909, thence from 1901 to 1955 the shore eroded an amount ranging from 150 to 250 feet. Total change between 1859 and 1955 consisted of seaward movement of the shore averaging about 150 feet. From the point about 4500 feet from Bass Hole, to Nobscusset Harbor there was continued erosion from 1859 to 1955.

6. Nobscusset Harbor to Sesuit Harbor. - The three available surveys show general erosion between 1859 and 1955 amounting up to 100 feet. However in two short areas, each 1500 feet long, and located 1000 and 5000 feet east of the harbor there was accretion during the period 1859 and 1934. In both of these areas the shore receded to a point shoreward of the 1859 line during the period 1934 to 1955.

7. Sesuit Harbor to Quivett Creek. - Between 1859 and 1955 there has been accretion in a fillet 160 feet wide at Sesuit harbor and extending about 3,000 feet easterly. From thereon to Quivett Creek there has been general erosion. Between 1859 and 1934 there was accretion of about 75 feet beyond the 1955 line to the point about 3,000 feet easterly of the harbor. However, this material eroded during the period 1934 - 1955. At the mouth of Quivett Creek the shore has receded about 600 feet since 1859.

8. Quivett Creek to Namskakot Creek. - Between these two locations the shore changes have been mixed during the period of record. Adjacent to Quivett Creek inlet for a distance of about 500 feet the shore has receded about 600 feet, from there on to Herring River, Brewster there has been accretion averaging about 250 feet. From Herring River eastward for about 4,500 feet there was progressive erosion during the period 1859 - 1955, generally moving the shore about 100 feet landward. For a distance of about 3,500 feet eastward erosion averaged about 40 feet between 1859 and 1934, then accretion occurred in amount of about 100 feet between 1934 and 1955. From this point to about 1500 feet west of Namskakot Creek there was general slight erosion between 1859 and 1934 then accretion more than offsetting the previous erosion during the period 1934 - 1955. At the entrance to Namskakot Creek there was recession ranging from about 200 to 600 feet.

9. Namskakot Creek to Herring River, Eastham. - Between 1849 and 1934 there was erosion up to 200 feet from Namskakot Creek to a point just south of Rock Creek. From there to Herring River there was general accretion ranging up to 200 feet. From 1934 to 1953 there was general erosion of from 200 to 300 feet and ranging up to 500 feet. The general change between 1849 and 1953 was erosion ranging from about 300 to 500 feet.

10. Herring River to Hatches Creek (Town Line). - During the period 1849 - 1953 the north bank of Herring River moved northward about 500 feet, and the area 3,000 feet northward thereof changed very little,

consisting of erosion up to about 50 feet along the southward portion and accretion up to about 75 feet along the northward portion. From that point to about 3000 feet south of Hatches Creek there was general erosion ranging from 100 to 150 feet during the period of 1849 - 1953. Along this same reach the change during the period 1938 - 1952 was small consisting generally of erosion ranging up to about 50 feet. Along the northerly 3000 feet of shore the bar retreated between 500 and 600 feet.

11. Wellfleet Harbor. - The area of greatest erosion north of Hatches Creek and along the inside of Wellfleet Harbor is between Hatches Creek and Silver Spring Brook and along the south side of Lieutenant Island. The former area has eroded generally from 300 to 700 feet at a rather uniform rate since 1849. Along the south side of Lieutenant Island there was alternate erosion and accretion with little overall change between 1849 and 1934. However, between 1934 and 1938-43 the shore receded from 300 to 500 feet. It is assumed that the hurricane of 1938 was the principal cause of this large change. Along the east side of Lieutenant Island there was rather uniform erosion as follows: 1848 - 1909, 300 feet; 1909 - 1934, 200 feet; 1934 - 1943, 70 feet; 1943 - 1953, 60 feet. Except for isolated points, erosion is general and in varying amounts throughout the harbor. The largest of the accretion areas are located at Field Point, the east shore of the Cove, Shirt-tail Point, and at each side of the entrance of Herring River. The progression of the shore line where occurring, may be due at least in part to deposition of spoil from dredging the harbor.

12. Jeremy Point to Griffin Island. - The trend of the changes along this reach of shore has been toward a straight alignment and lengthening of the point. During the period 1849 - 1953, the northerly 6000 feet of shore eroded about 350 feet, the adjoining 3,000 feet moved seaward about 150 feet, the next adjoining shore move landward from about 200 to 350 feet and extended southward about 4,000 feet. The southward tip of the tombolo moved westward about 1,000 feet and extended to its present length during the period 1848-1933. Throughout the reach the shore line as shown by the various surveys, has migrated generally in a shoreward direction since 1849.

13. Griffin Island to Pamet River. - Except for a barrier bar which formed at the northerly end of Griffin Island there was a general landward movement of the shore during the period 1848 through 1954. The amount of the movement varied but the largest volume change in a short reach occurred near the north limit of the reach where the shore receded up to 200 feet. The movement as shown by surveys of 1848, 1909, 1933, 1938 and 1954 were not constant, but the long range effect was of landward movement of the shore.

14. Pamet River to Pilgrim Beach. - This reach extends northward to triangulation station "Knowles - 1940", see Plate 9. The Pamet River entrance was very unstable prior to construction of the jetties

in about 1937. The river had various inlets through the beach and in 1909 was 2,500 feet northward of its present location. Since construction of the jetties a barrier bar has formed in the lee of the north jetty. Since 1938-43 the northerly end of the bar has moved landward about 200 feet. For a distance of about 8,000 feet the shore moved landward during the period 1833-1954. However between 1833 and 1848 this portion moved seaward up to 100 feet then retreated landward of its present position then migrated seaward to its present position. Northward from this point to the north end of the reach there has been a general seaward movement of the shore up to about 220 feet since 1833. Here again movement has not been constant. During the period 1833 - 1848 the shore moved seaward up to 300 feet, during 1848-1933 it moved up to 100 feet, during 1933 - 1938 it moved seaward a small amount, and during 1938 - 1954 it moved seaward again up to a distance of about 50 feet.

15. Pilgrim Beach. - From triangulation station Knowles to the old inlet to Pilgrim Lake the overall change between 1833 and 1954 has been recession beginning at the east and increasing to about 350 feet about 1,000 feet east of the old inlet. After the closure of the inlet during the period during the period 1833-1857 there was a large recession and the shore was apparently unstable during the period 1890 to 1933. Since that time there has been little change except at the lake closure. At the old inlet, which was closed during the period 1833 - 1857, there has been a consistent accretion causing the shore line to move seaward about 1,300 feet.

16. Pilgrim Lake to Provincetown Dike. - Immediately west of the old Pilgrim Lake inlet to about 3,000 feet west the shore line receded about 400 feet during the period 1833 - 1954, and from that point to about 3,000 feet further west the erosion uniformly decreased to a negligible amount. From the point about 6,000 feet west of Pilgrim Lake throughout Provincetown the erosion occurring between 1833 and 1954 amounted to less than 50 feet, the major portion occurring prior to the survey of 1848.

17. Provincetown (New) Beach. - This area extends from Hatches Harbor southeastward for about 9,000 feet. In 1833 the area was composed of an irregular shore with a barrier beach about 1,000 feet offshore. The barrier was breached at the center of the reach. The breached barrier apparently began eroding and moving landward until by the survey of 1890 there was a new shore line about 400 to 700 feet seaward of the inner line of 1833. In its stabilization the shore line had receded in 1909, moved seaward in 1933, receded again by 1938 and in 1954 was generally 500 feet seaward of the 1833 line.

18. Long Point. - Long Point outward from Provincetown (New) Beach has been subject to rather mixed variations in the high water shore line as shown by the various surveys. However, the actual

change as shown by the survey of 1833 when compared to that of 1954 has been recession of up to 300 feet in the northerly 8,000 feet of shore. From that point to the outer end there has been general accretion placing the shore line at the end approximately 500 feet seaward of the 1833 line. The tip of the point also extended outward almost 1,000 feet between 1833 and 1954. Local interests have estimated that the spit grew about 250 feet during the last three years.

Offshore Changes

19. Offshore changes along the shore from Corn Hill in Truro to the outer end of Cape Cod were available for use in this report. These changes were shown as changes in the 6, 12, 18, 24 and 30-foot contours as shown by surveys made in 1833-35, 1856, 1867 and 1933.

20. During the period 1833-1933 all contours moved shoreward in the area just west of Pamet River inlet. In the vicinity of Corn Hill to just west of Pilgrim Beach the 6, 12 and 18-foot contours moved seaward an average distance of about 200 to 300 feet and the 24 and 30-foot contours moved shoreward an average distance of about 300 feet. From the Pilgrim Beach area through Provincetown to the lea of Long Point all contours moved shoreward distances ranging up to about 1,000 feet.

21. Along Provincetown (New) Beach and around the outer side of Long Point the contour changes during this period of time were more complex and varied. Opposite the developed State Beach where the barrier beach was breached in the early 19th century the 6, 12 and 18-foot depth contours moved shoreward significant distances ranging up to 800 feet. Eastward to a point about 3,000 feet from the outer end of Long Point the contour changes were smaller and generally in a seaward direction. Throughout the area the 24 and 30-foot depth contours changed small distances generally in a seaward direction. Along the outer 3,000 feet of the point the contours all moved in a seaward direction. Seaward of the end of the 6-foot contour moved about 1,000 feet, the 12-foot about 500 feet, the 18-foot about 350 feet, the 24-foot about 150 feet and the 30-foot about 100 feet. Thus while the beach is moving seaward it also appears to be growing steeper.

APPENDIX F

COST OF IMPROVEMENTS

1. General. - Estimates of first costs and annual charges have been made for each of the areas of detailed study. Unit prices are based on recent bids on projects in the general area. Preauthorization costs are added to the first costs of projects involving Federal aid. Preauthorization costs were shared equally by the United States and the Commonwealth of Massachusetts.

2. Detailed Cost Estimates. - First costs are computed on the basis of price levels of July 1959. An interest rate of 2.5 percent for Federal funds and 3 percent for Non-Federal funds was used throughout. Amortization is based on a useful project life of 50 years. Plans are shown on Plate 23.

A. Town Neck Beach.

(1) <u>First Cost (Cooperative portion)</u>		
Beach Fill, 165,000 c.y. sand @ \$0.80		\$132,000
Contingencies		21,000
	Subtotal	\$153,000
Engineering and Design		5,000
	Subtotal	\$158,000
Supervision and Administration		13,000
Total First Cost		\$171,000
Federal Share		\$ 57,000
Non-Federal Share		114,000
(2) <u>First Cost (Federal Only)</u>		
Raise Jetty, 1,400 tons stone @ \$5.00		\$ 7,000
Contingencies		1,000
	Subtotal	\$ 8,000
Engineering and Design		1,000
	Subtotal	\$ 9,000
Supervision and Administration		1,000
Total First Cost		\$ 10,000
(3) <u>Annual Charges (Federal)</u>		
Investment		
Sand Fill		\$ 57,000
Jetty Modification		10,000
Preauthorization		1,500
Total Investment		\$ 68,500

Interest	\$ 1,700
Amortization	700
Periodic Nourishment 1,300 c.y. @ \$0.80	1,000
Maintenance	
Jetty, 20 tons @ \$5.00	100
Total Annual Charges	<u>\$ 3,500</u>

(4) Annual Charges (Non-Federal)

<u>Investment</u>	
Sand Fill	\$114,000
Preauthorization Costs	1,500
Total Investment	<u>\$115,500</u>

Interest	\$ 3,500
Amortization	1,000
Periodic Nourishment 2,700 c.y. @ \$0.80	2,000
Total Annual Charges	<u>\$ 6,500</u>

(5) Summary

	<u>Construction Cost</u>	<u>Annual Charges</u>
Federal	\$ 67,000	\$ 3,500
Non-Federal	<u>114,000</u>	<u>6,500</u>
	<u>\$181,000</u>	<u>\$10,000</u>

B. Spring Hill Beach

(1) First Cost (all non-Federal)

Beach Fill, 266,000 c.y. sand @ \$0.80	\$213,000
Contingencies	31,000
Subtotal	<u>\$244,000</u>
Engineering and Design	7,000
Subtotal	<u>\$251,000</u>
Supervision and Administration	20,000
Total Construction Cost	<u>\$271,000</u>

(2) Annual Charges

Interest	\$ 8,100
Amortization	2,400
Beach Replenishment, 5,000 c.y. @ \$0.80	4,000
Total Annual Charges	<u>\$ 14,500</u>

C. Brewster Bluffs (all non-Federal)

(1) First Cost (all non-Federal)

Sand Fill, 150,000 c.y. @ \$0.70	\$105,000
Contingencies	15,000
Subtotal	<u>\$120,000</u>

Engineering and Design		\$ 4,000
	Subtotal	\$124,000
Supervision and Administration		10,000
Total Construction Cost		\$134,000
(2) <u>Annual Charges</u>		
Interest		\$ 4,000
Amortization		1,200
Maintenance		
Sand Fill, 1,000 c.y. @ \$0.70		800
Total Annual Charges		\$ 6,000

E. Thumpertown Beach

(1) <u>First Cost (Cooperative Project)</u>		
Sand Fill, 50,000 c.y. sand @ \$0.70		\$ 35,000
Groin, 1,500 tons stone @ \$4.50		7,000
Contingencies		6,000
	Subtotal	\$ 48,000
Engineering & Design		2,000
		\$ 50,000
Supervision and Administration		4,000
Total Construction Cost		\$ 54,000
Federal Share		\$ 18,000
Non-Federal Share		36,000

(2) <u>Annual Charges (Federal)</u>		
Investment		
Project		\$ 18,000
Preauthorization		1,200
Total Investment		\$ 19,200
Interest		\$ 500
Amortization		200
Total Annual Charges		\$ 700

(3) <u>Annual Charges (Non-Federal, Public Beach)</u>		
Investment		
Construction Cost		\$ 36,000
Preauthorization Cost		1,200
Total Investment		\$ 37,200
Interest		\$ 1,100
Amortization		300
Maintenance		
Sand Fill, 1,000 c.y. @ \$0.70		700
Groin, stone, 20 tons @ \$4.50		100
Total Annual Charges		\$ 2,200

(4) Summary

	<u>Federal</u>	<u>Non-Federal</u>	<u>Total</u>
Construction Cost	\$18,000	\$36,000	\$54,000
Annual Charges	700	2,200	2,900

F. Eastham Beaches (Private)

- (1) First Cost (Non-Federal Only)
Sand Fill, 260,000 c.y. @ \$0.70
Groins, 11,200 tons stone @ \$4.50
Contingencies

	\$182,000
	50,000
	35,000
Subtotal	<u>\$267,000</u>

Engineering and Design

Subtotal	<u>8,000</u>
	<u>\$275,000</u>

Supervision and Administration
Total Construction Cost

	22,000
	<u>\$297,000</u>

- (2) Annual Charges (Non-Federal, Private Beach)
Construction Cost

\$297,000

Interest

\$ 8,900

Amortization

2,600

Maintenance

Sand Fill, 5,000 c.y. @ \$0.70

3,500

Groins, 100 tons @ \$4.00

400

Total Annual Charges

\$ 15,400

G. Indian Neck

- (1) First Cost (Non-Federal Only)
Stone Groin, 300 tons @ \$5.00
Contingencies

	\$ 1,500
	300
Subtotal	<u>\$ 1,800</u>

Engineering and Design

Subtotal	<u>200</u>
	<u>\$ 2,000</u>

Supervision and Administration
Total Construction Cost

	200
	<u>\$ 2,200</u>

- (2) Annual Charges

Interest

\$ 70

Amortization

19

Maintenance

Groin, stone, 6 tons @ \$5.00

30

Total Annual Charges

\$ 119

H. Pilgrim Beach (Non-Federal Only)

(1) First Cost

Groins, 20,000 tons of stone @ \$4.50	\$ 90,000
Contingencies	13,000
Subtotal	\$103,000
Engineering and Design	3,000
Subtotal	\$106,000
Supervision and Administration	7,000
Total Construction Cost	\$113,000

(2) Annual Charges

Interest	\$ 3,400
Amortization	1,000
Maintenance, stone 200 tons @ \$4.50	900
Total Annual Charges	\$ 5,300

I. Provincetown State Beach (Cooperative Project)

(1) First Cost

Sand Fill, 120,000 c.y. @ \$0.65	\$ 78,000
Groins, 21,500 tons stone @ \$4.50	97,000
Sea Wall	
Concrete, 950 c.y. @ \$30.00	\$28,500
Stone, 1,800 tons @ \$5.00	9,000
Excavation, 7,000 c.y. @ \$0.50	3,500
Backfill & Patching, L.S.	2,000
Total Sea Wall	\$ 43,000
Contingencies	33,000
Estimated Total Contract Cost	\$251,000
Engineering and Design	8,000
Supervision and Administration	20,000
Total First Cost	\$279,000
Federal	\$ 93,000
Non-Federal	186,000

(2) Annual Charges (Federal)

Investment	
Project Cost	\$ 93,000
Preauthorization Cost	1,000
Total Investment	\$ 94,000
Interest	\$ 2,300
Amortization	1,000
Total Annual Charges	\$ 3,300

(3) Annual Charges (Non-Federal)

<u>Investment</u>		
Project Cost		\$186,000
Preauthorization Cost		1,000
Total Investment		<u>187,000</u>
Interest		5,600
Amortization		1,600
Maintenance		
Sand, 2,000 c.y. @ \$0.65	\$1,300	
Stone, 200 tons @ \$4.50	900	
Seawall	<u>100</u>	
Total		2,300
Total Annual Charges		<u>\$ 9,500</u>

(4) Summary

	<u>Federal</u>	<u>Non-Federal</u>	<u>Total</u>
First Cost	\$93,000	\$186,000	\$279,000
Annual Charges	3,300	9,500	12,800

APPENDIX G

ESTIMATE OF BENEFITS

1. General. - Benefits are estimated only for the projects which are eligible for Federal participation in the cost of protection. These projects are Town Neck Beach in Sandwich, Thumpertown Beach in Eastham and Provincetown State Beach.

2. Benefits evaluated are non-Federal public or private resulting from elimination of direct damage including reduction in maintenance to existing structures and recreational benefits. Values estimated are based on prive levels of July 1959.

3. Town Neck Beach.

a. Direct Damages Prevented. - Except for 100 feet of Federal owned frontage adjacent to the jetty and 1,100 feet of privately owned frontage adjacent thereto the shore front between the Cape Cod Canal jetty and Sandwich Harbor is owned by the Town of Sandwich. Private lands and buildings are located behind the public owned land. If no project were constructed, it is estimated that public lands and buildings valued at \$89,000 would be lost. This value includes paved streets and parking areas evaluated at \$0.50 per square foot. In addition, private lands and buildings valued at \$245,000 would be lost. When a lot is eroded back to the point that less than 25 feet depth remains, it is assumed that the entire lot is unusable. This benefit is $\$89,000 + 245,000 = \$334,000/50$ equals \$6,700 per year over the 50-year life of project. Present maintenance of groins is estimated to be equal to replacement of 500 tons per year. It is estimated that widening the beach would reduce this maintenance to 200 tons per year. Prior to complete destruction, it is estimated that the town would expend at least \$50,000 over the life of the project repairing wave erosion damage to streets and parking areas. It is estimated that at least 1,500 cubic yards of sand lost from the area is carried over the jetty into Cape Cod Canal, that one-half of the material remains and should be removed therefrom.

b. Recreational Benefits. - Due to the nearness of Scusset State Beach, it is considered that Town Neck Beach will not attract significant transient usage. Its location, however, makes it convenient to several cottage developments inland from the shore. It is assumed that widening and stabilizing the beach will increase its desirability and therefore increase attendance an average of 100 visits per day or about 9,000 visits per year. Conversely, if no corrective measures are undertaken, it is considered that usage of the beach will decline by about 3,000 visits per year.

c. Summary. - Annual benefits to result from a project at Town Neck Beach are as follows:

<u>Type of Benefit</u>	<u>Amount</u>
Elimination of loss of lands and buildings	\$ 6,700
Reduced maintenance to groins, 300 tons @ \$5.00	1,500
Reduced maintenance to streets and parking areas, \$50,000 ÷ 50 years	1,000
Elimination of transport of sand into canal, 1,500 cu. yards x $\frac{1}{2}$ x \$1.00	800
Increased beach attendance 9,000 x \$0.25	2,300
Elimination of loss of attendance, 3,000 x \$0.25	1,000
Total Annual Benefit	<u>13,300</u>

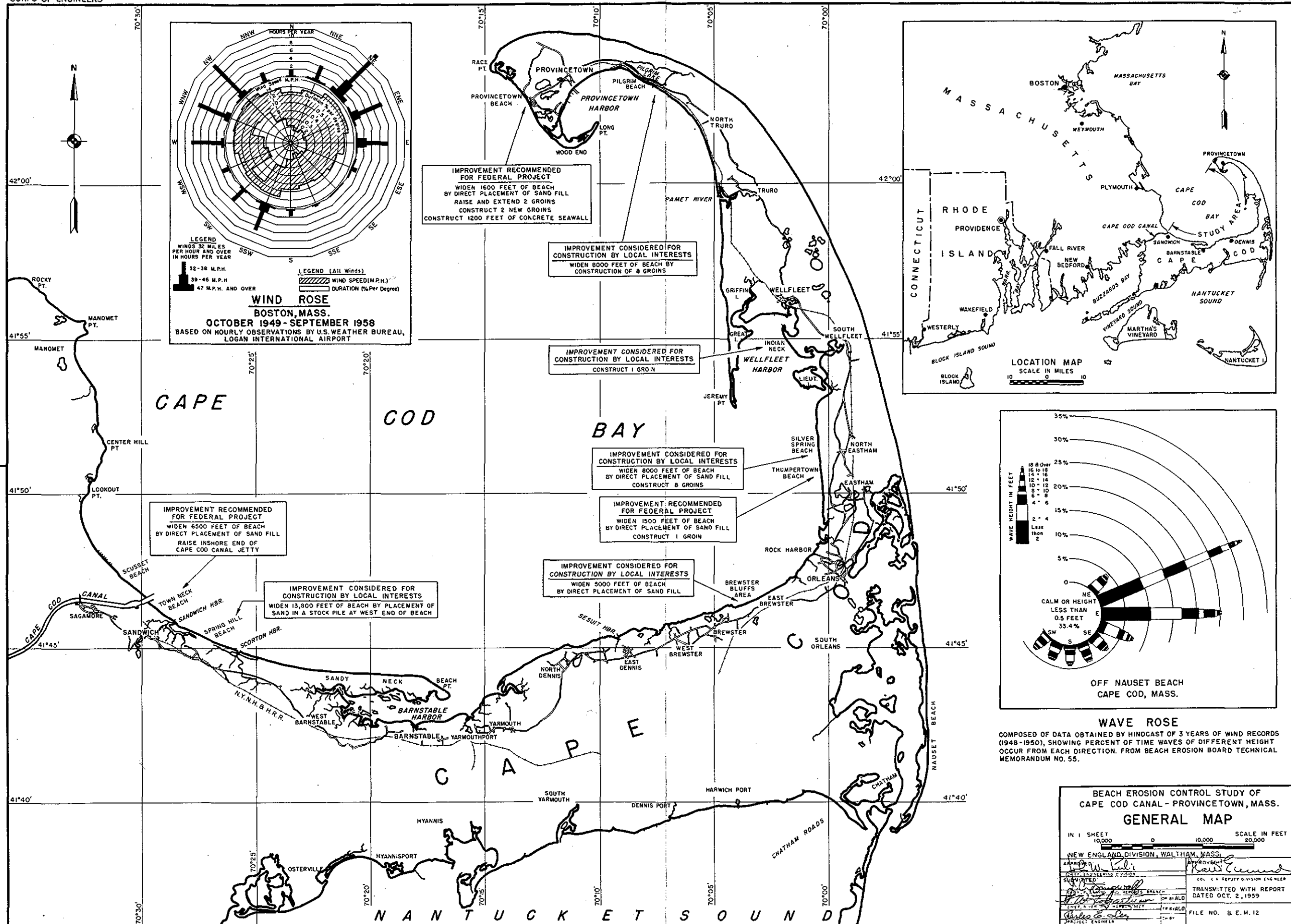
4. Thumpertown Beach, Eastham. - The following benefits apply only to the 1,523 feet of town owned beach. The shore in this area is retreating at a rate of about 1 foot per year. Land loss is 1,523 square feet per year. There is a paved parking area 200 x 200 feet located at the present beach berm. Loss of paved area would therefore be 200 square feet per year. Placing a beach and groin in this area would also eliminate maintenance of about \$100 per year to existing facilities. The existing beach width is considered adequate for present attendance during work-week days. It is considered too small for peak day use. The average widening of the beach amounts to about 75 feet. The added width would then have a capacity of 75' x 1,500' equals 112,500 square feet divided by 75 square feet per person equals 1,500 persons. Considering 50 percent capacity use on 25 peak days attendance would be 37,500 with a turnover of 2. A summary of annual benefits follow:

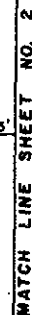
<u>Type of Benefit</u>	<u>Amount</u>
Beach recession, 1,523 sq. ft. x \$0.10	\$ 150
Loss of parking area, 200 sq. ft. x \$0.50	100
Reduction in maintenance of facilities	100
Recreation, 37,500 visits x \$0.25	<u>9,400</u>
	\$ <u>9,750</u>

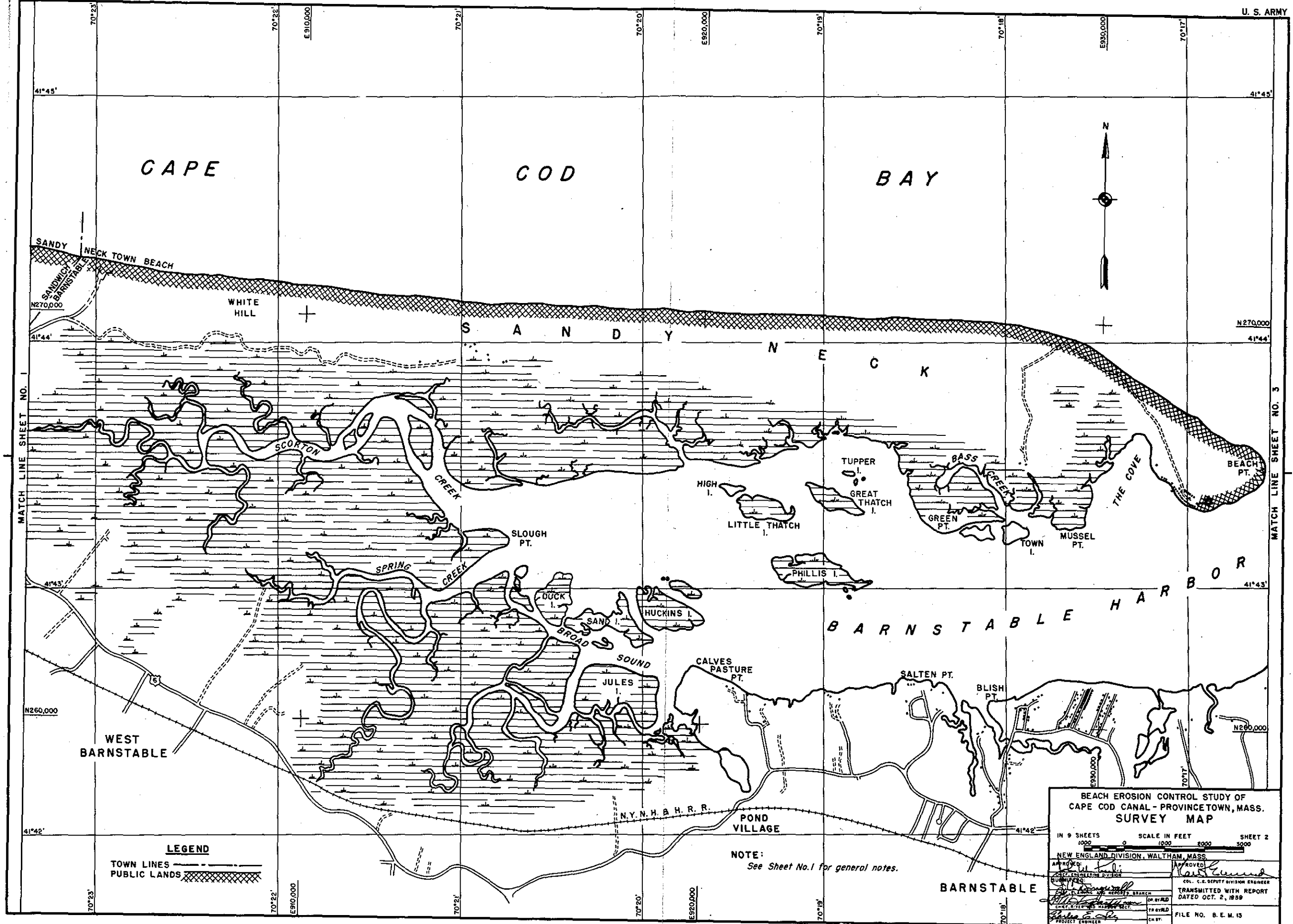
5. Provincetown Beach (State). - The average rate of erosion is approximately 2.5 feet per year. While the plan of protection will have beneficial effect throughout the developed beach area, it is considered that major benefit results to the 1,600 feet of shore behind the protection. Average loss of land is 1,600 x 2.5 equals 4,000 sq. feet per year. A paved parking area 1,800 feet long and 50 feet wide fronts the bathhouse. With no protection it is assumed the paving would be completely lost. The average annual area loss over the 50-year life of project would be 50/50 x 1800 equals 1800 square feet per year. The

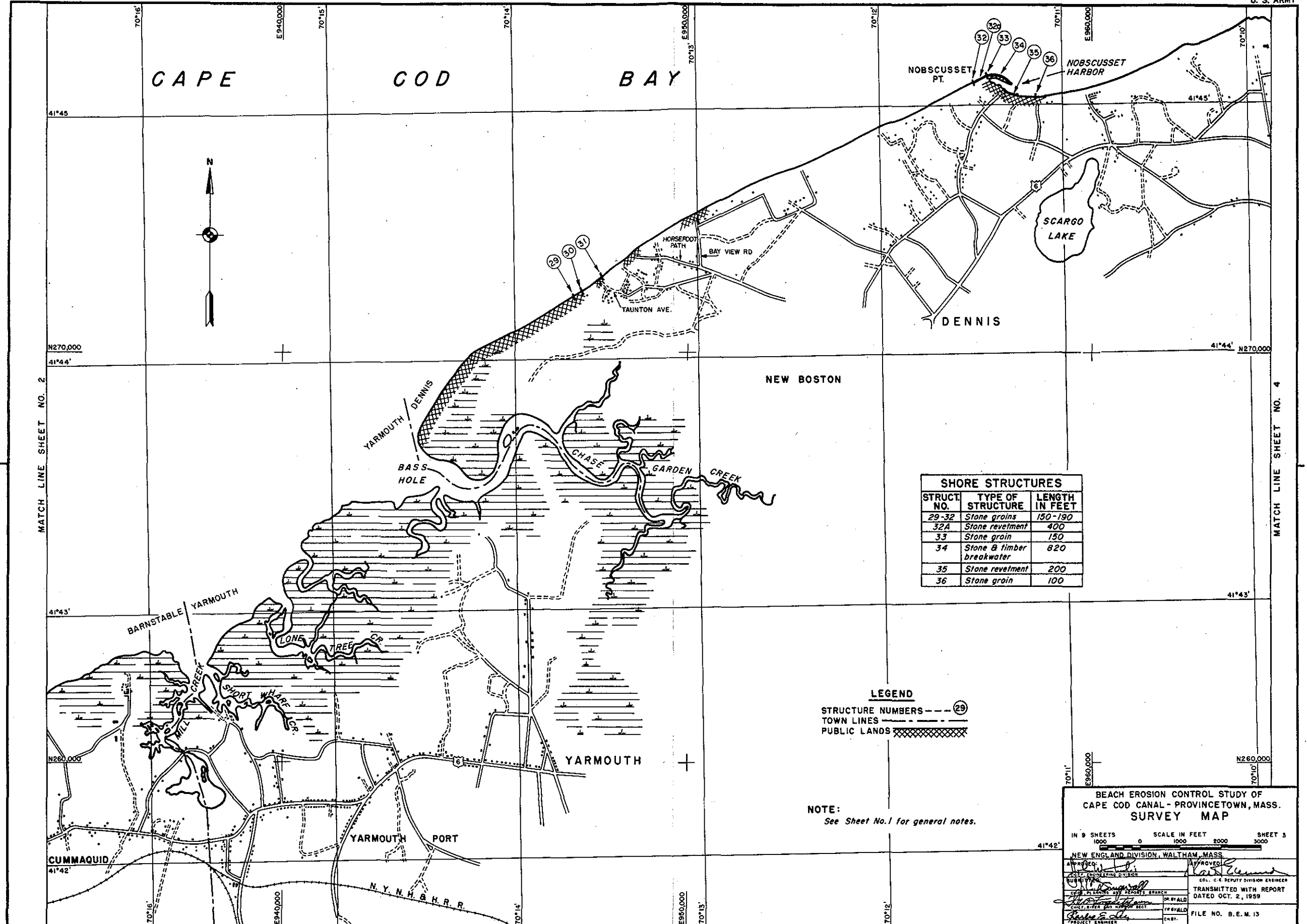
bath house valued at \$300,000 and water treatment plant valued at \$100,000 would be lost, in approximately 28 years, if no protection were provided and would require replacement. The benefit is assumed to be the elimination of the annual cost of replacement of the bath house and treatment plant. The cost of the two items were converted to present worth and distributed over the 50-year life of project in accordance with the method described in paragraph 15 of EM 1120-2-104. The benefit is $\$400,000 \times 0.5008765 \times .03526 = \$7,064$. Due to the length of the beach, there is more than adequate area for any reasonable assumption of usage. The available area is too far away from facilities to be desirable. It is considered that the added area will be used on 25 peak days per year and is worth \$0.15 per person. The added capacity is 70×1600 feet equals 112,000 square feet, which is allowing 75 sq. ft. per person provides capacity for 1500 persons. A summary of the annual benefits, as discussed above, follows:

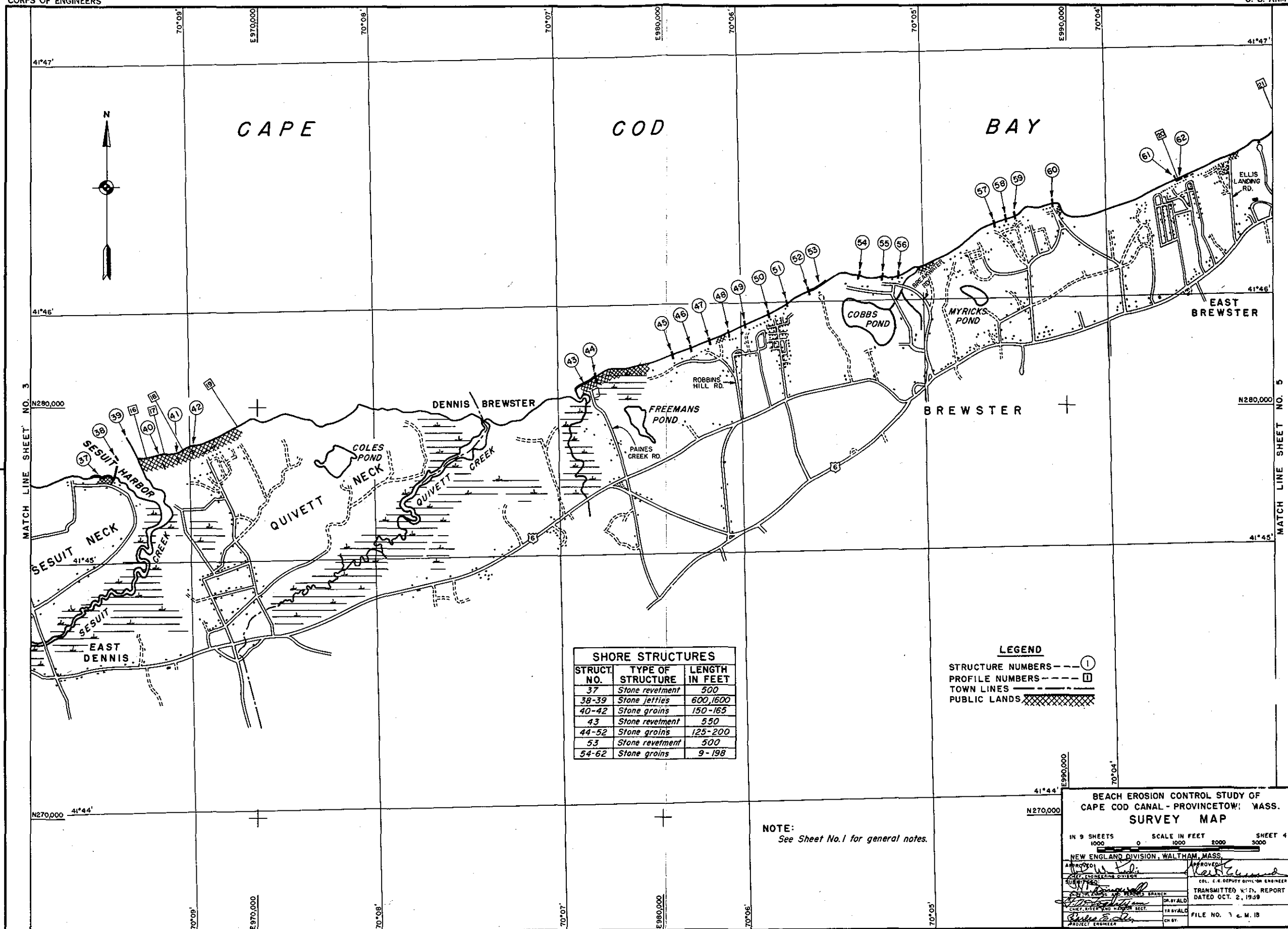
<u>Type of Benefit</u>	<u>Amount</u>
Loss of beach area, 4,000 sq. ft. @ \$0.10	\$ 400
Loss of paved parking area, 1800 sq. ft. @ \$0.50	900
Loss of bath house and treatment plant	7,100
Recreational, $1500 \times 2 \times 25 \text{ days} \times \0.15	<u>11,900</u>
Total	\$ 20,300

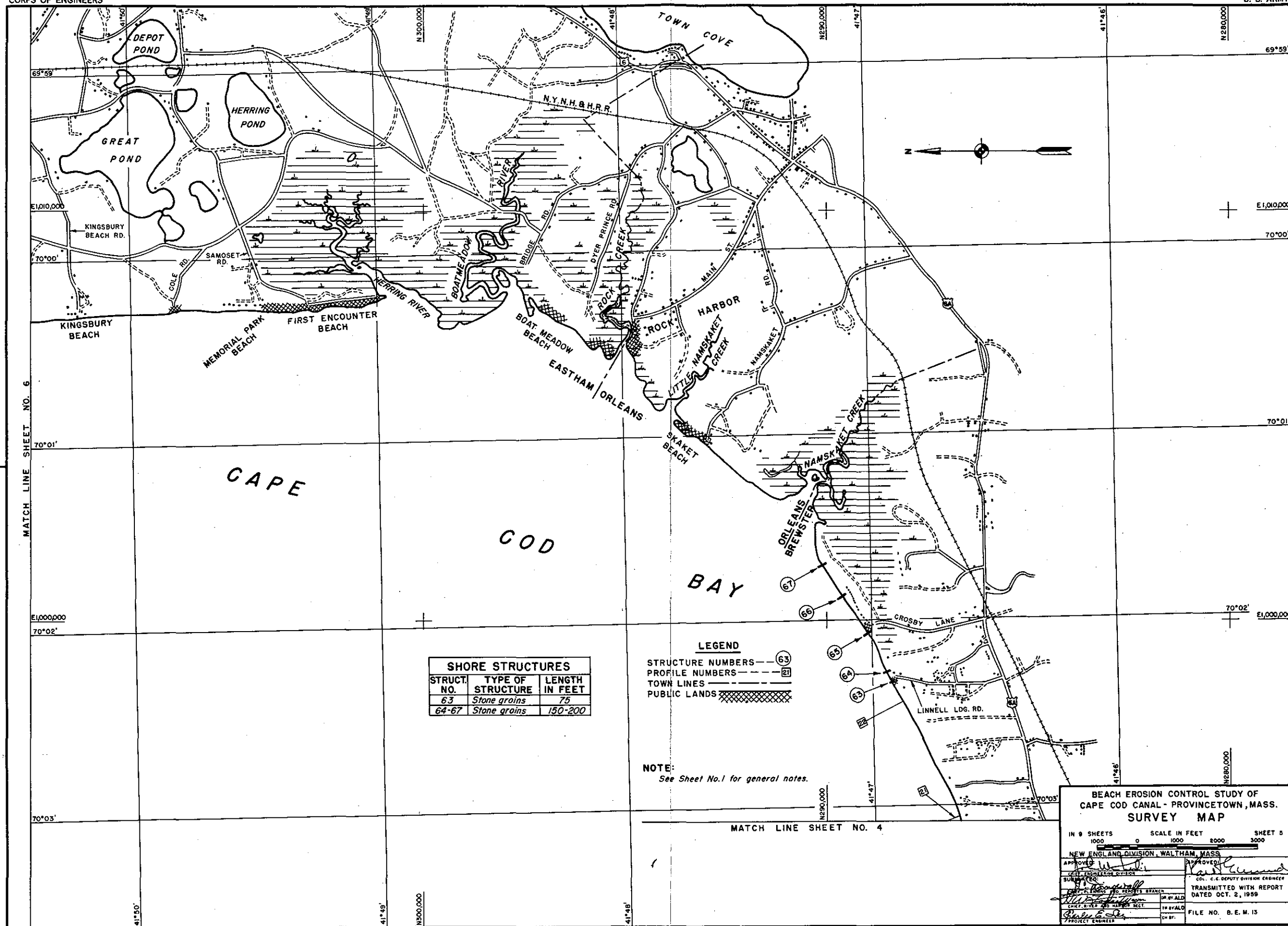


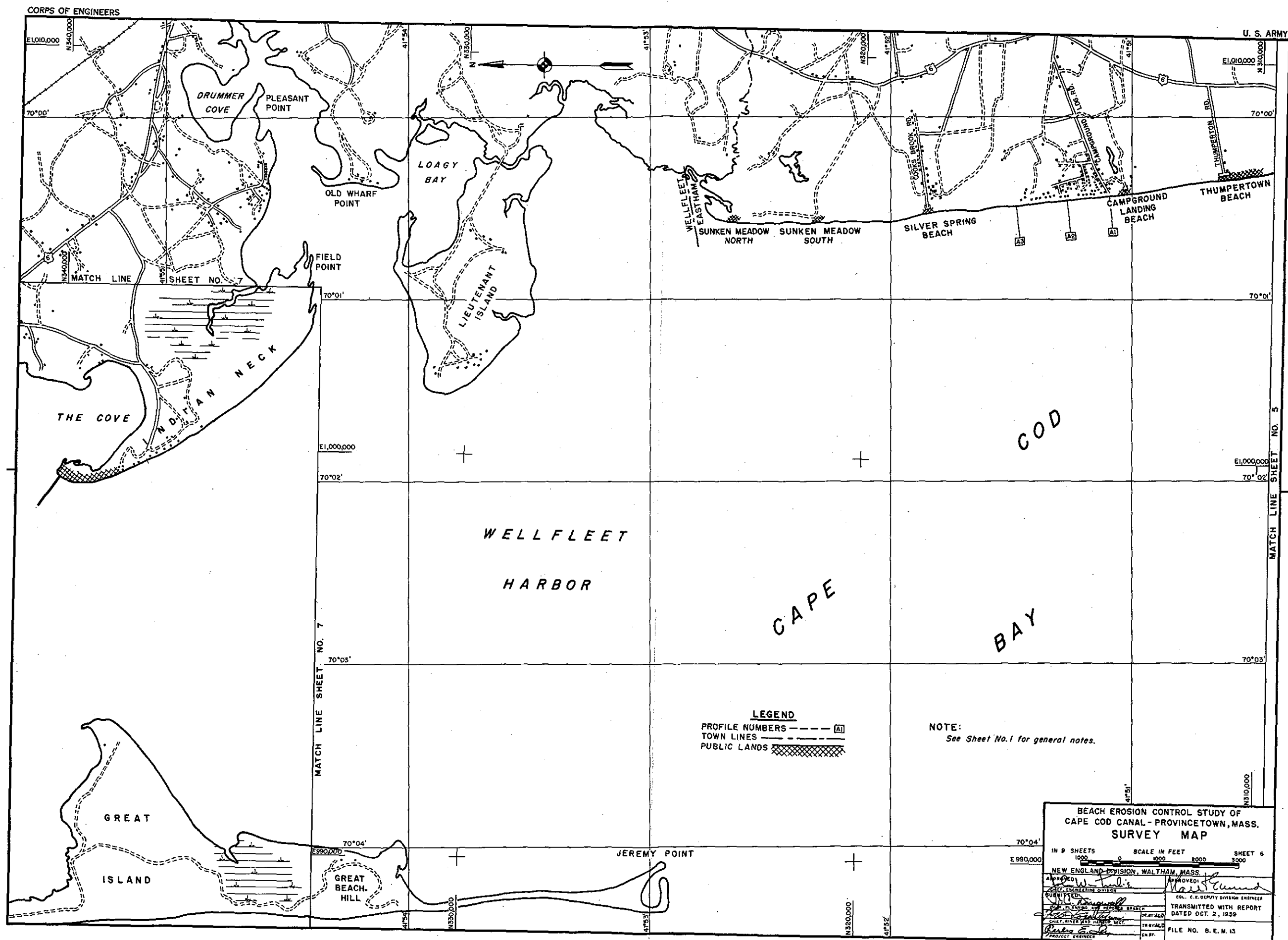


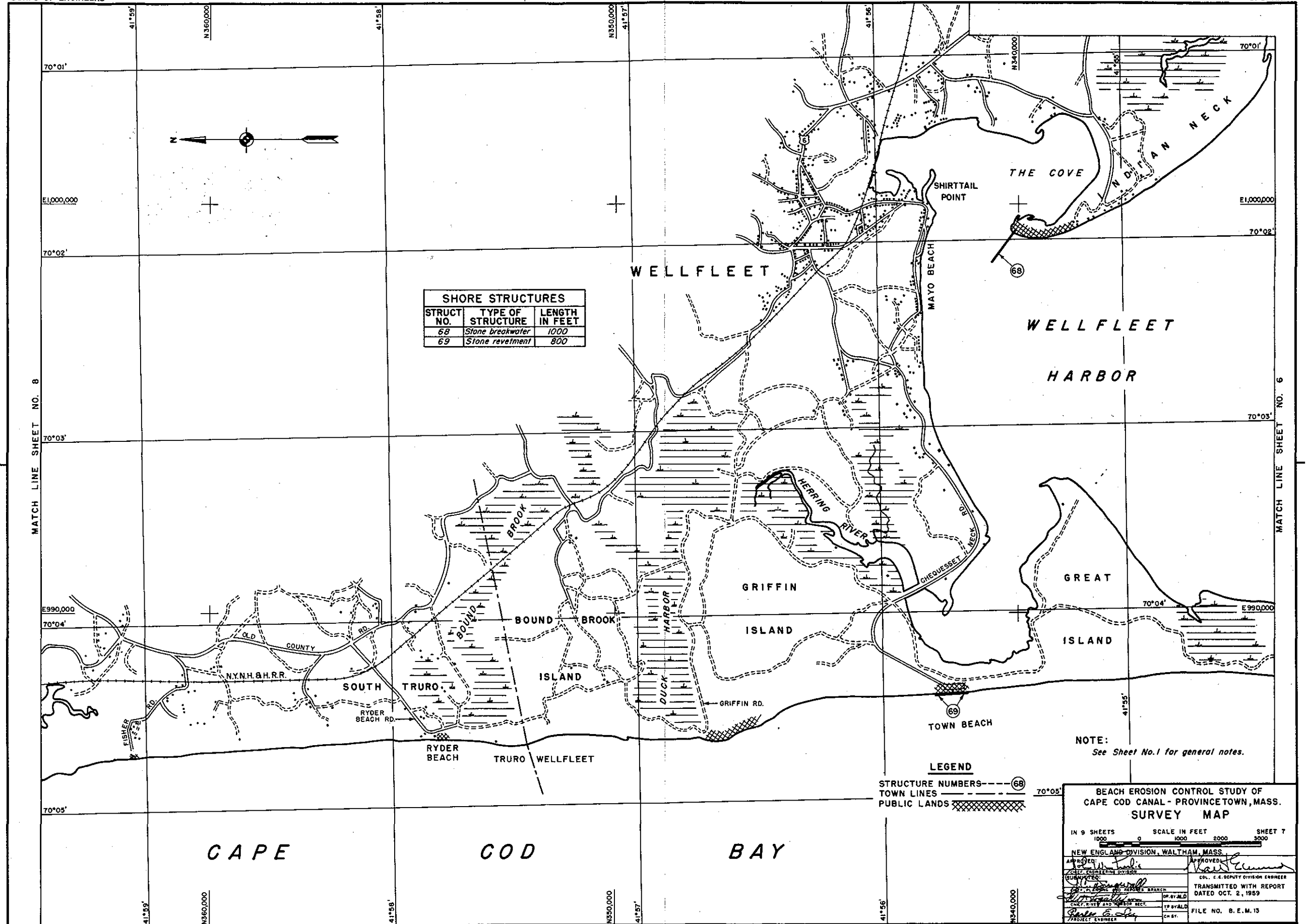


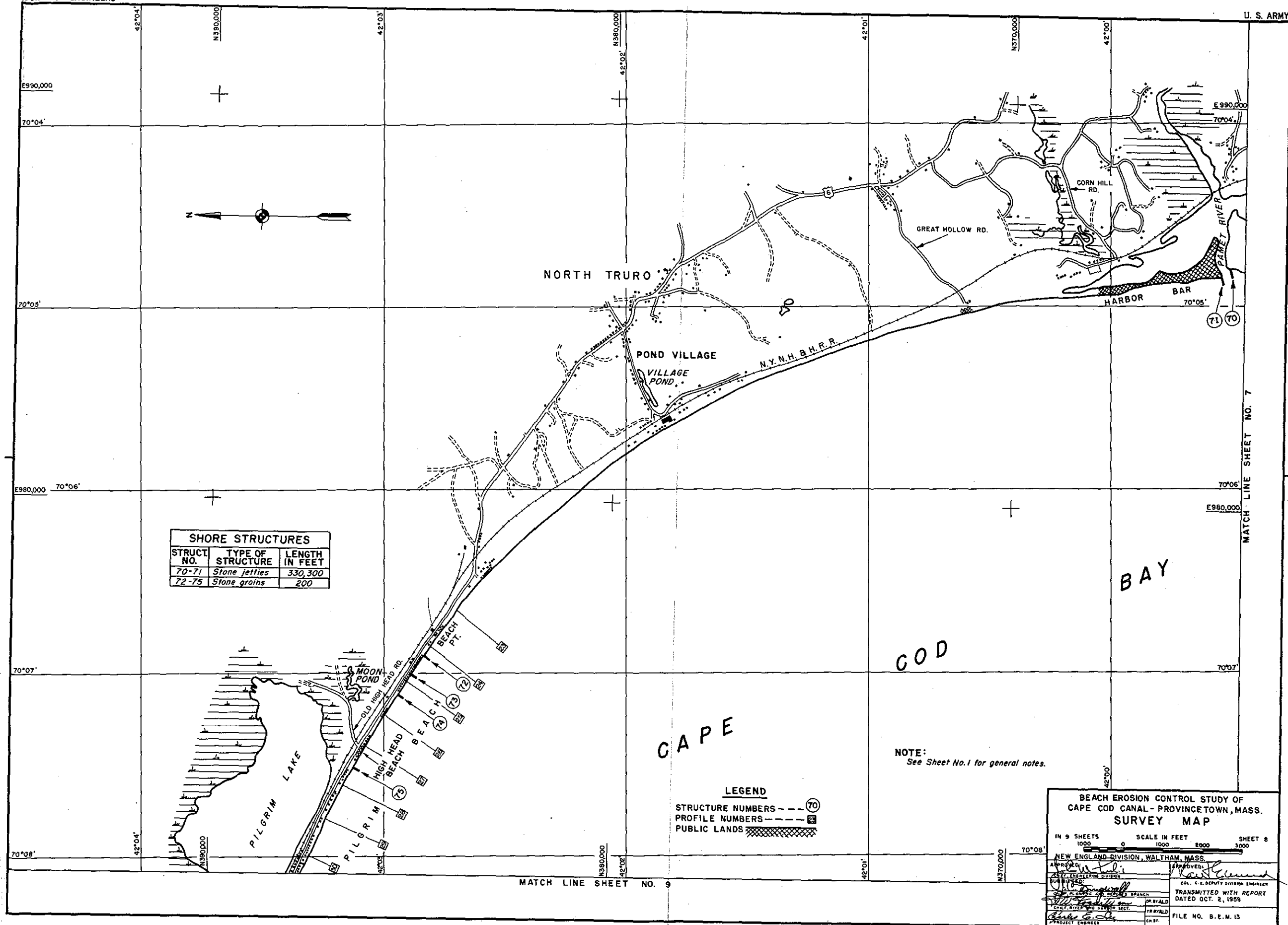


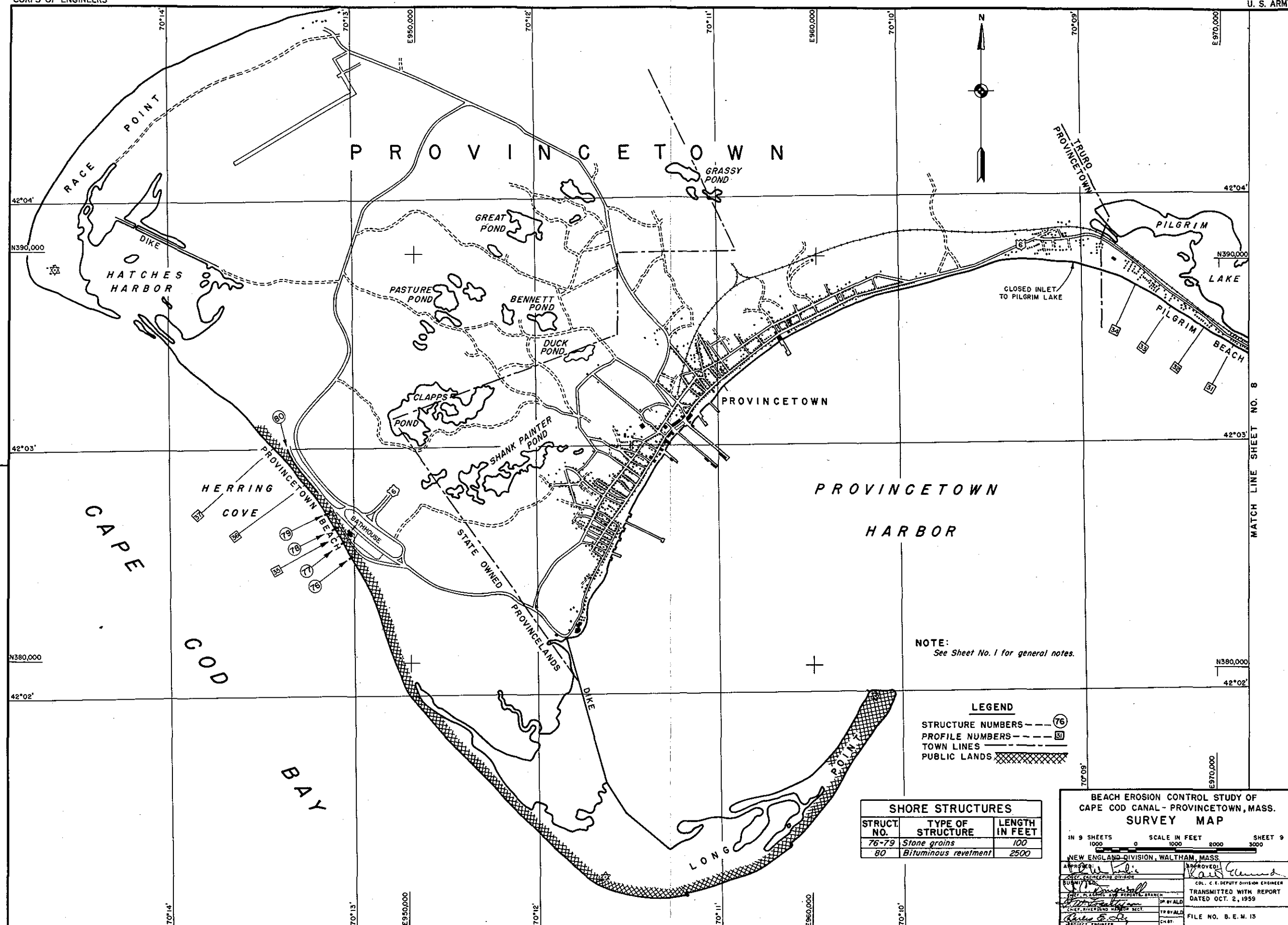


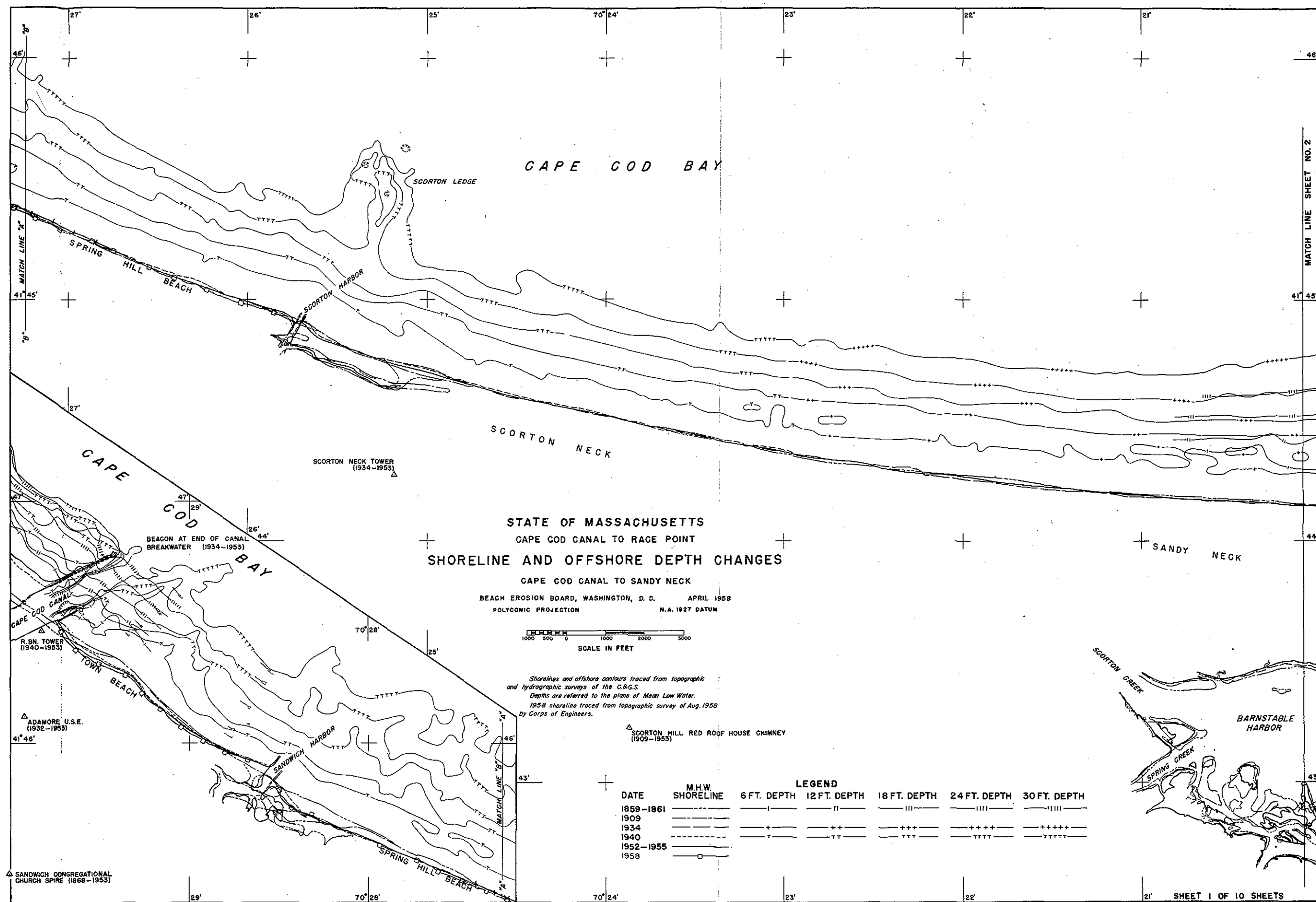


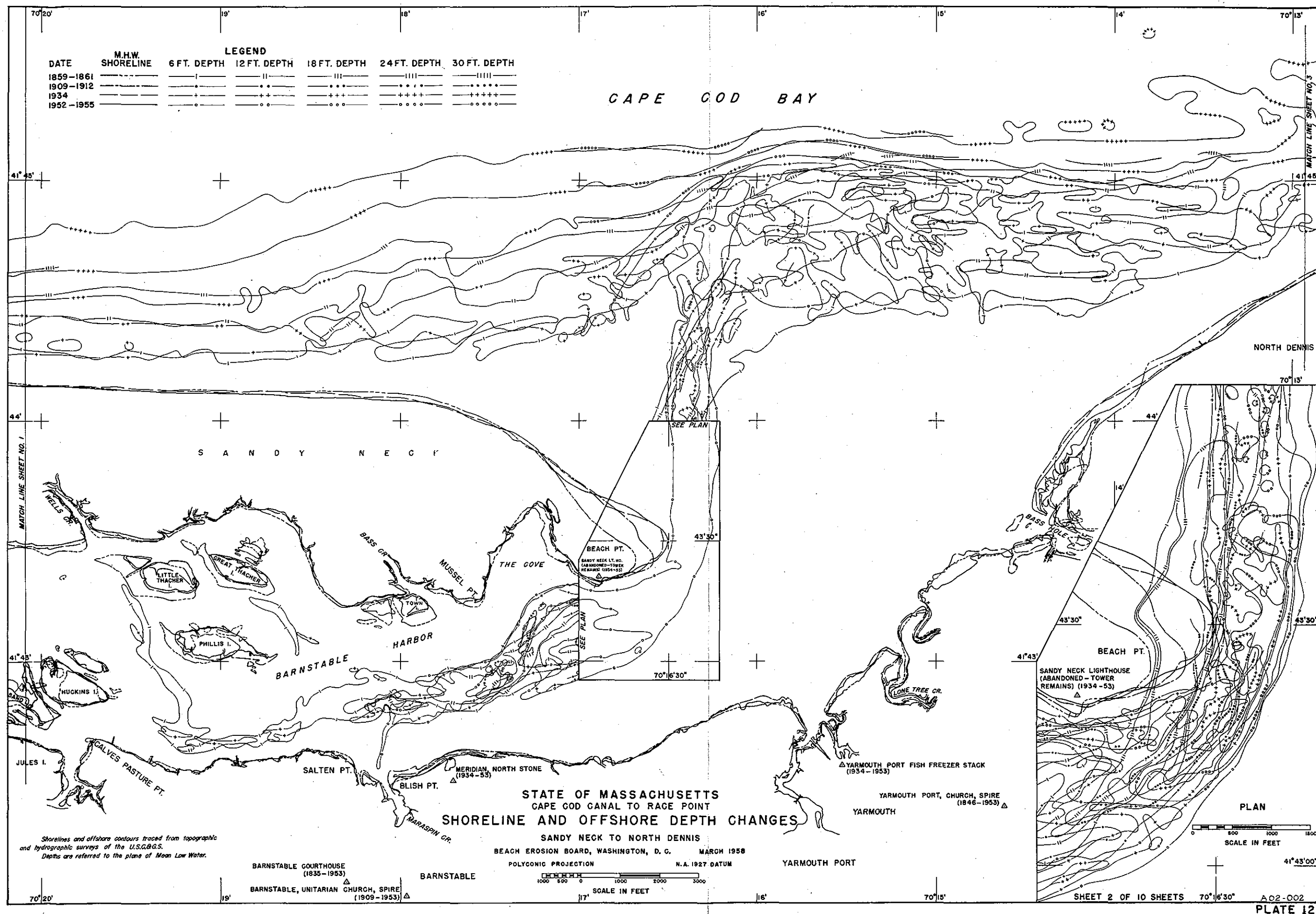


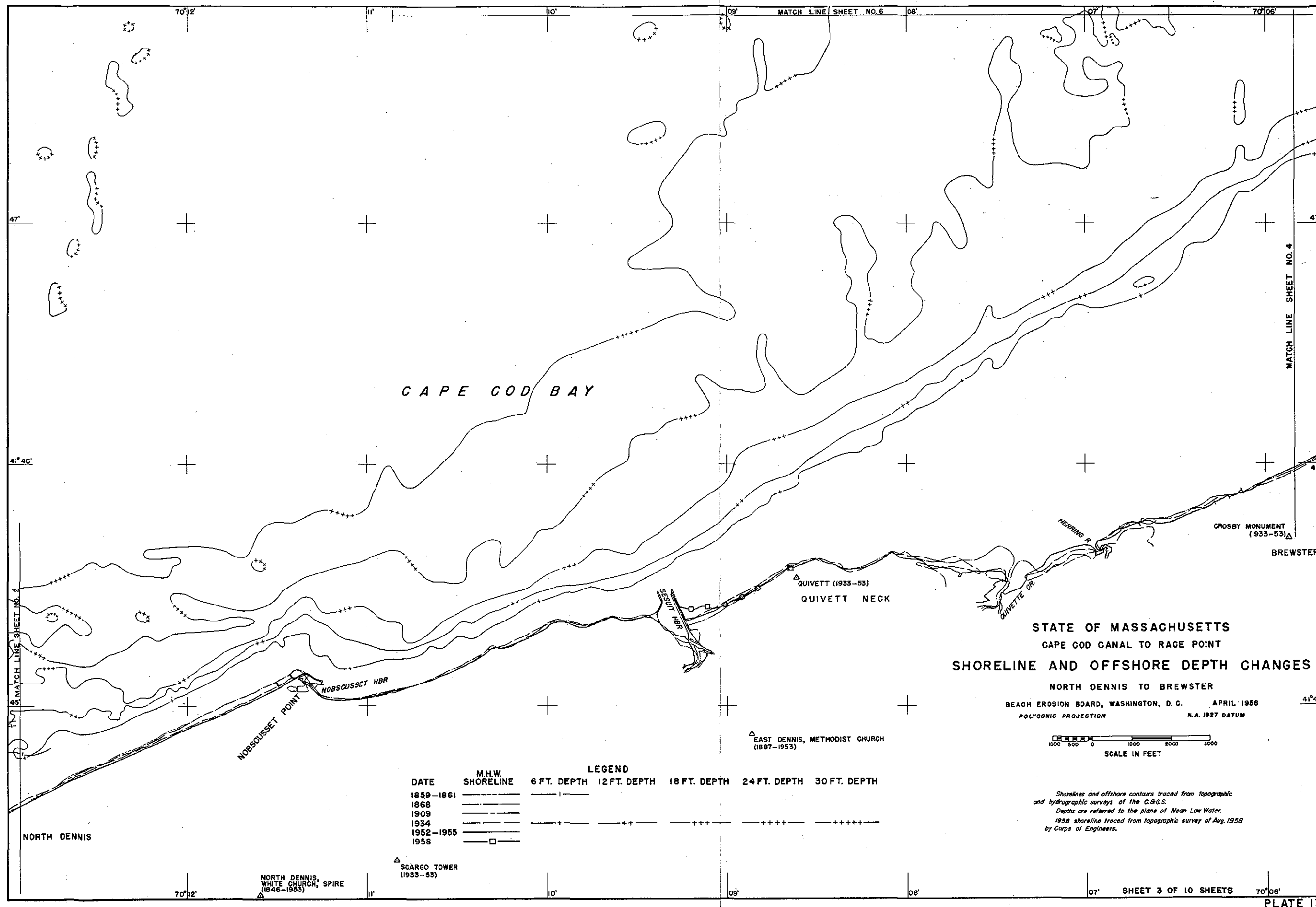


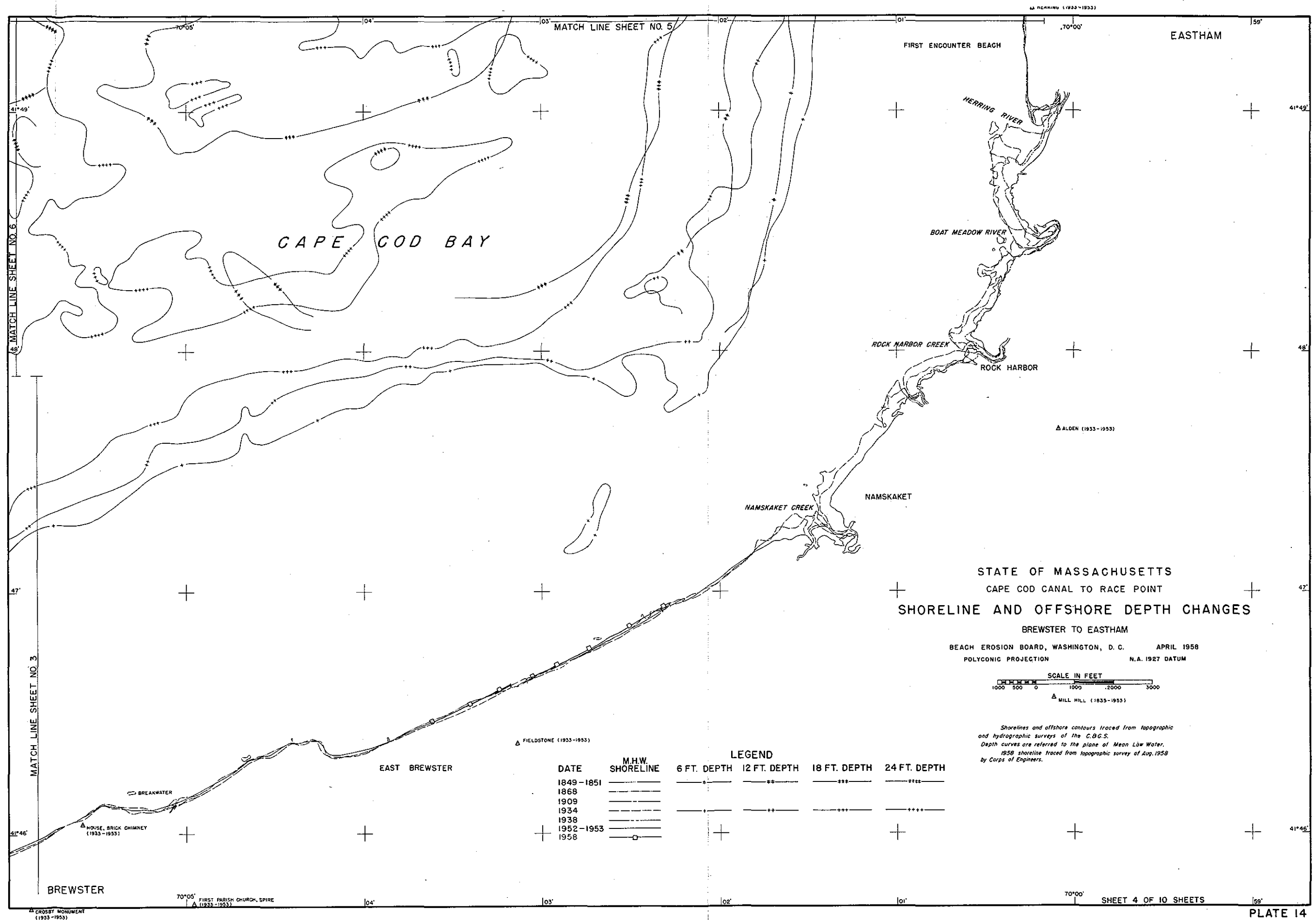


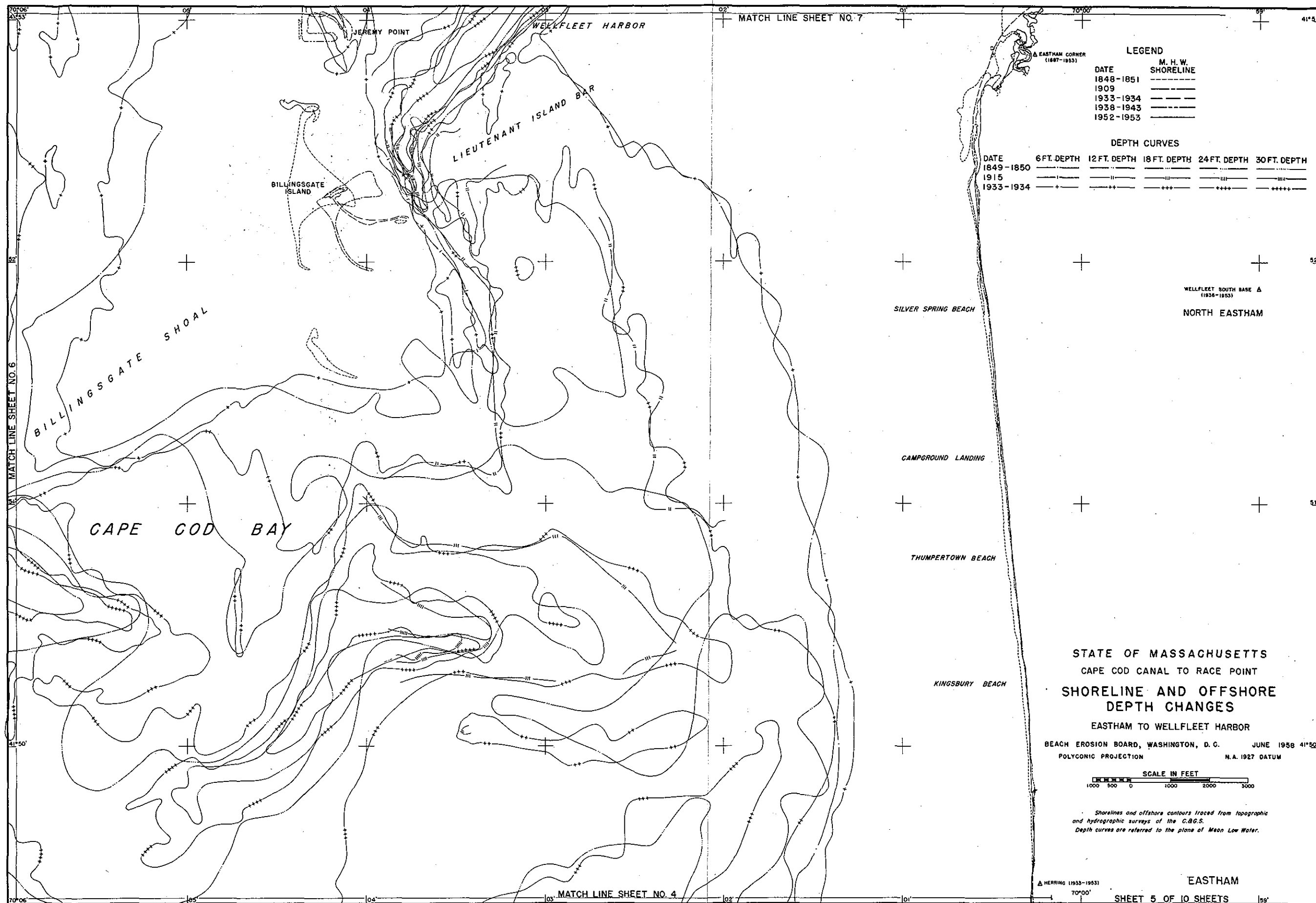


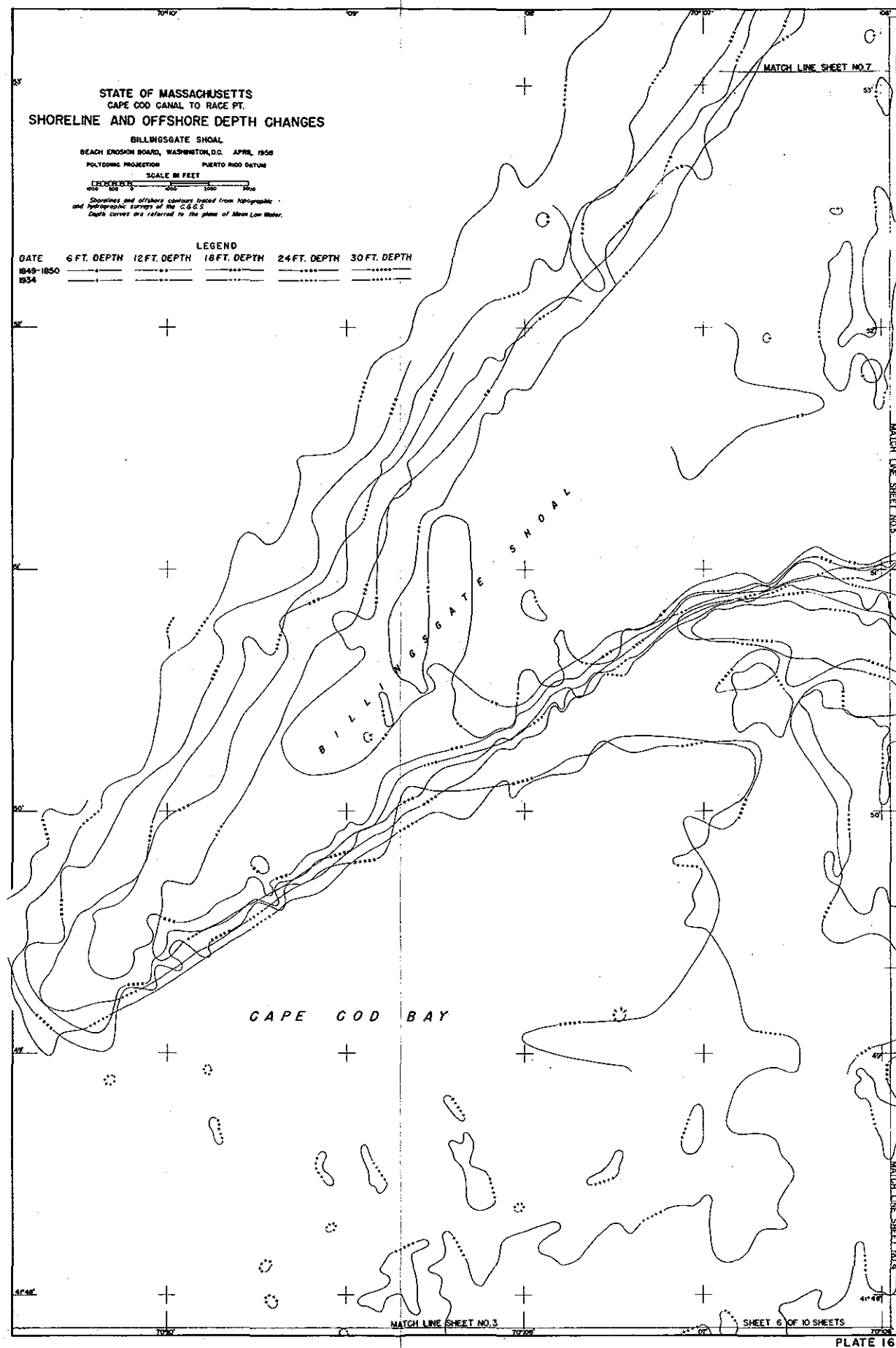


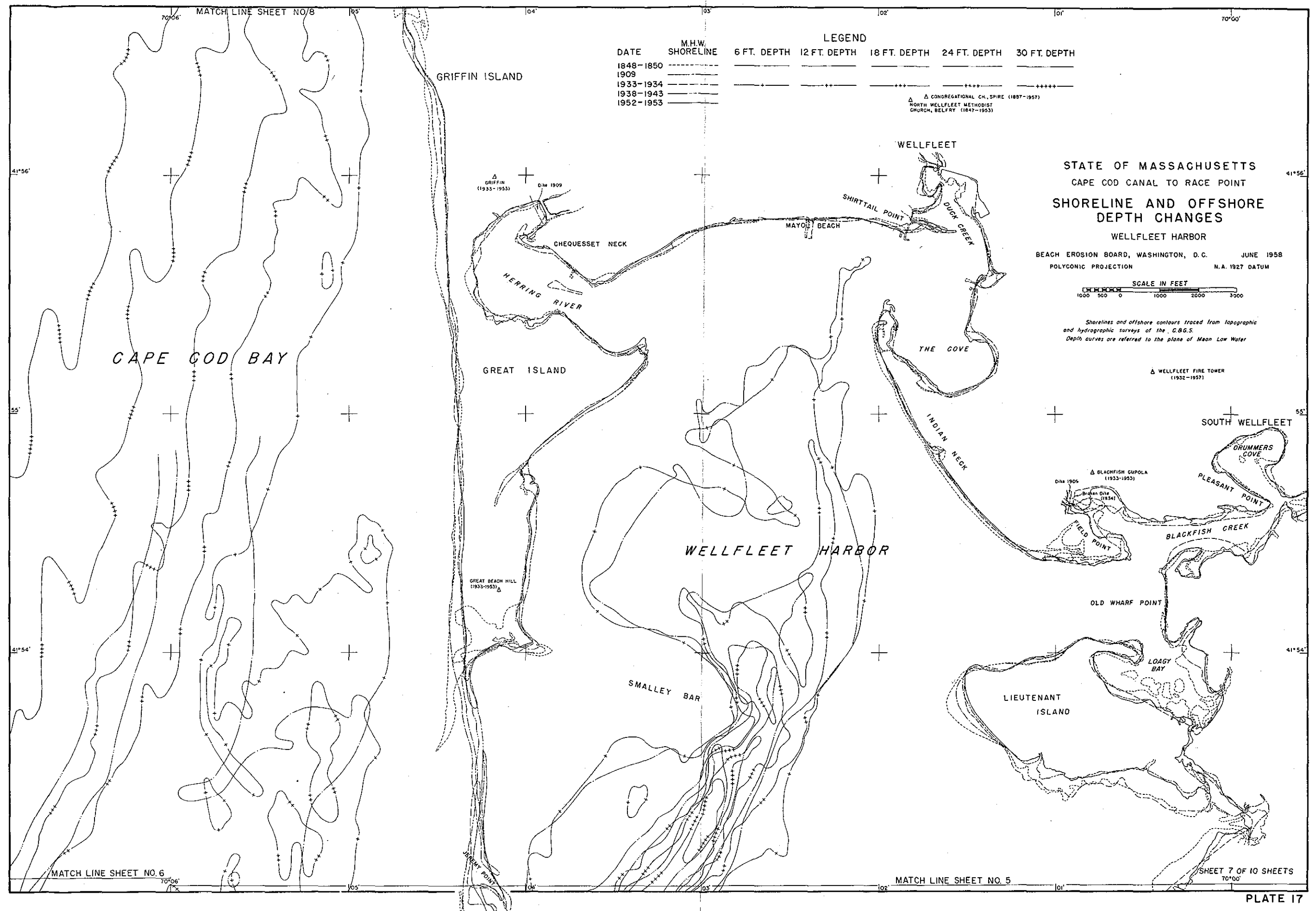


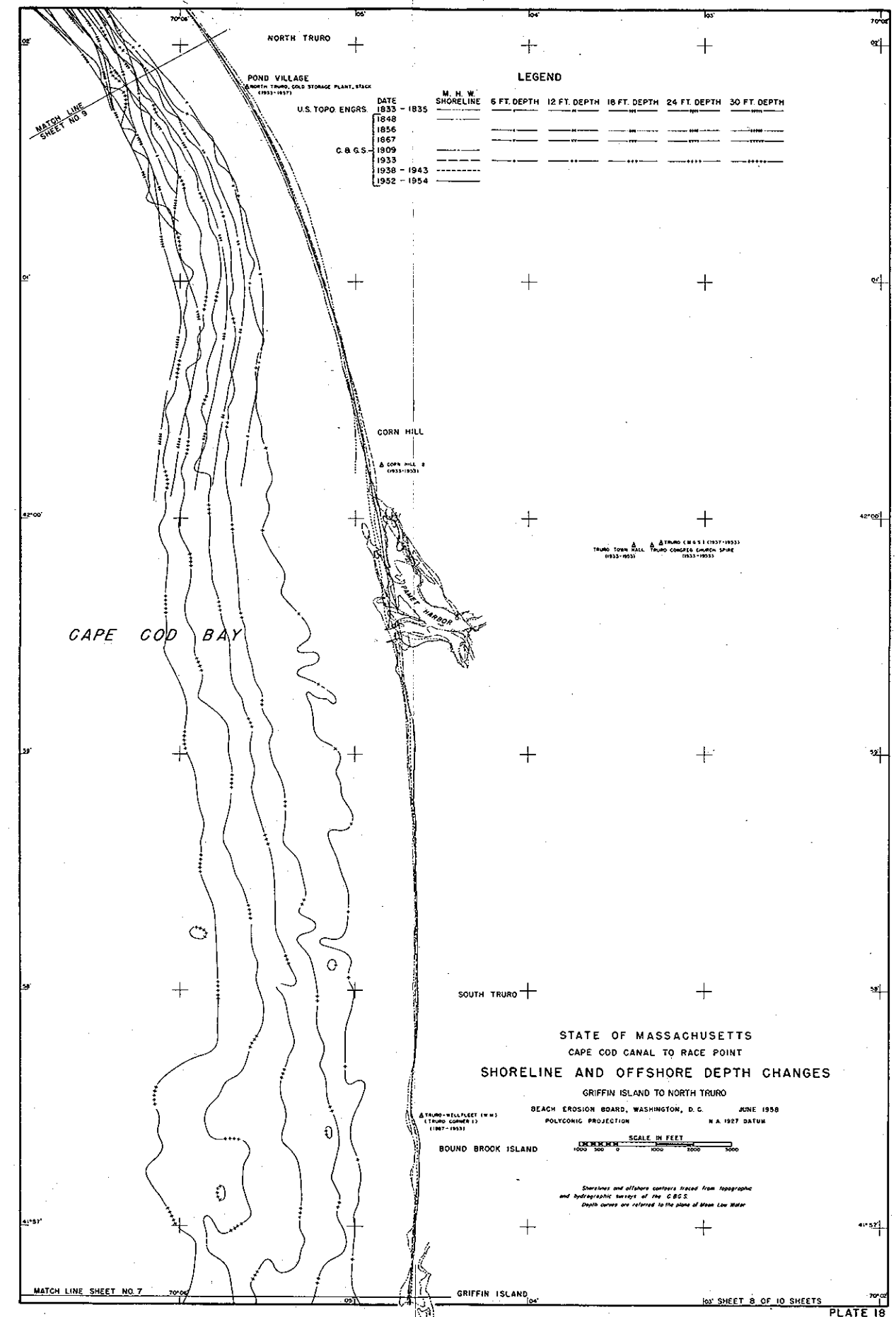


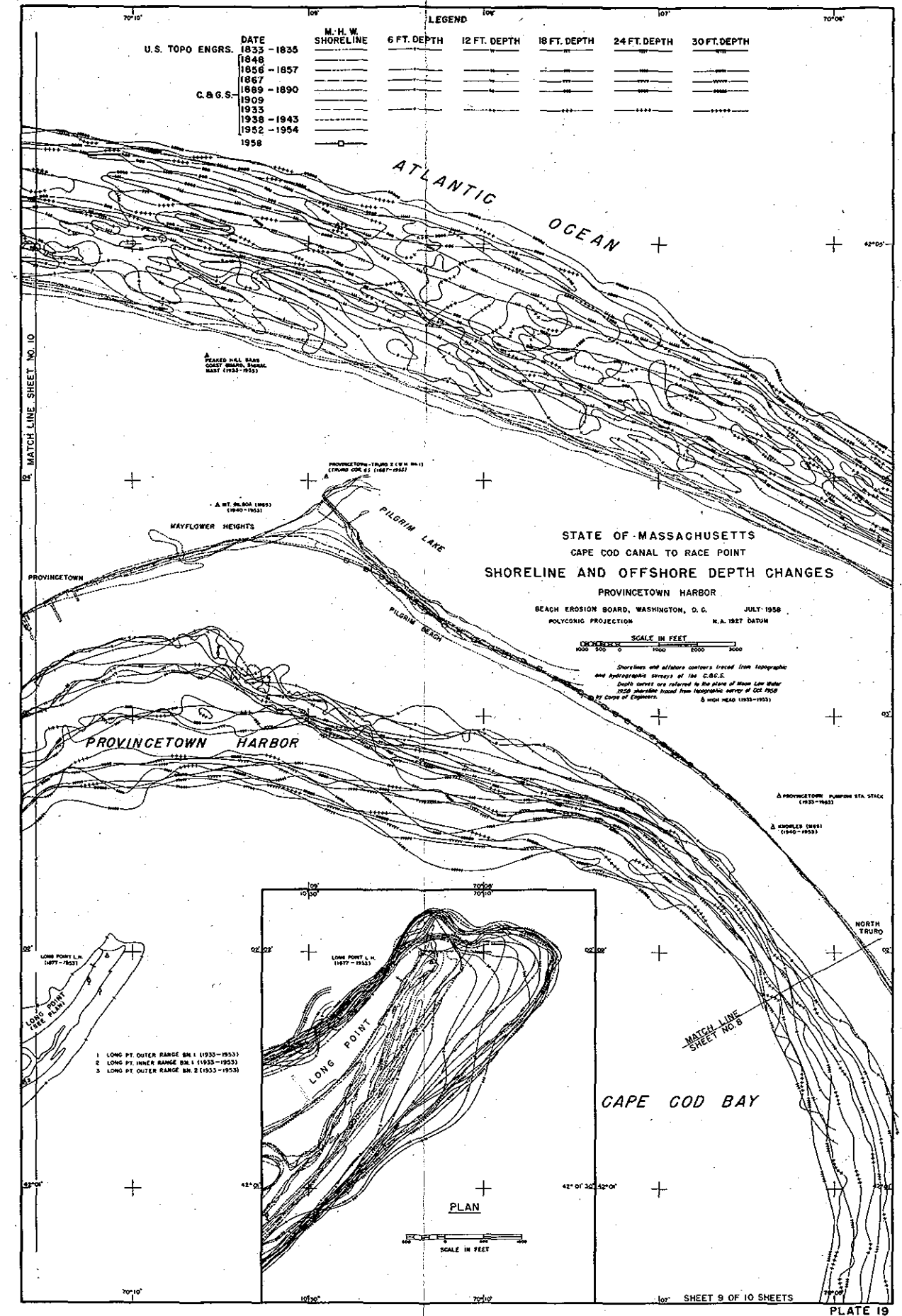


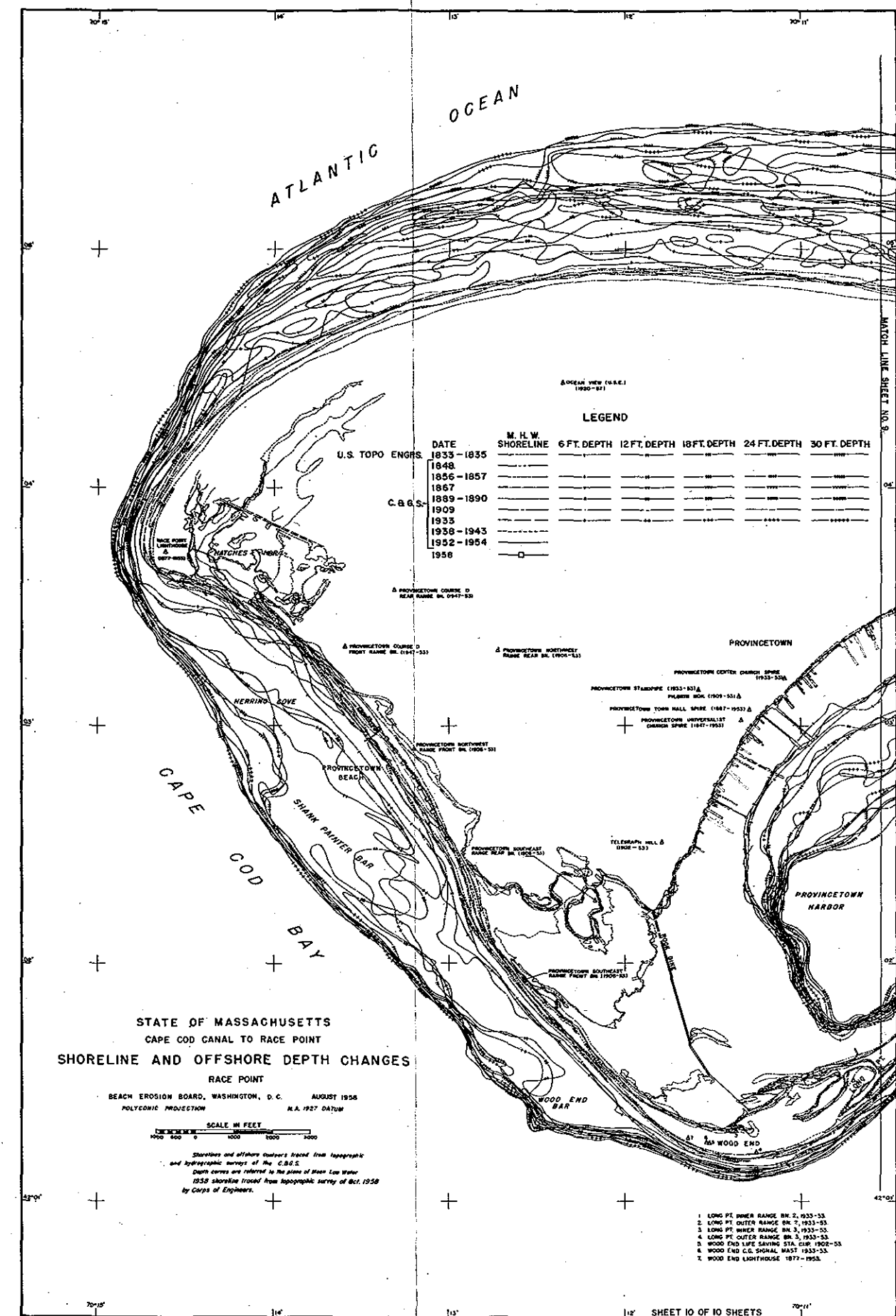


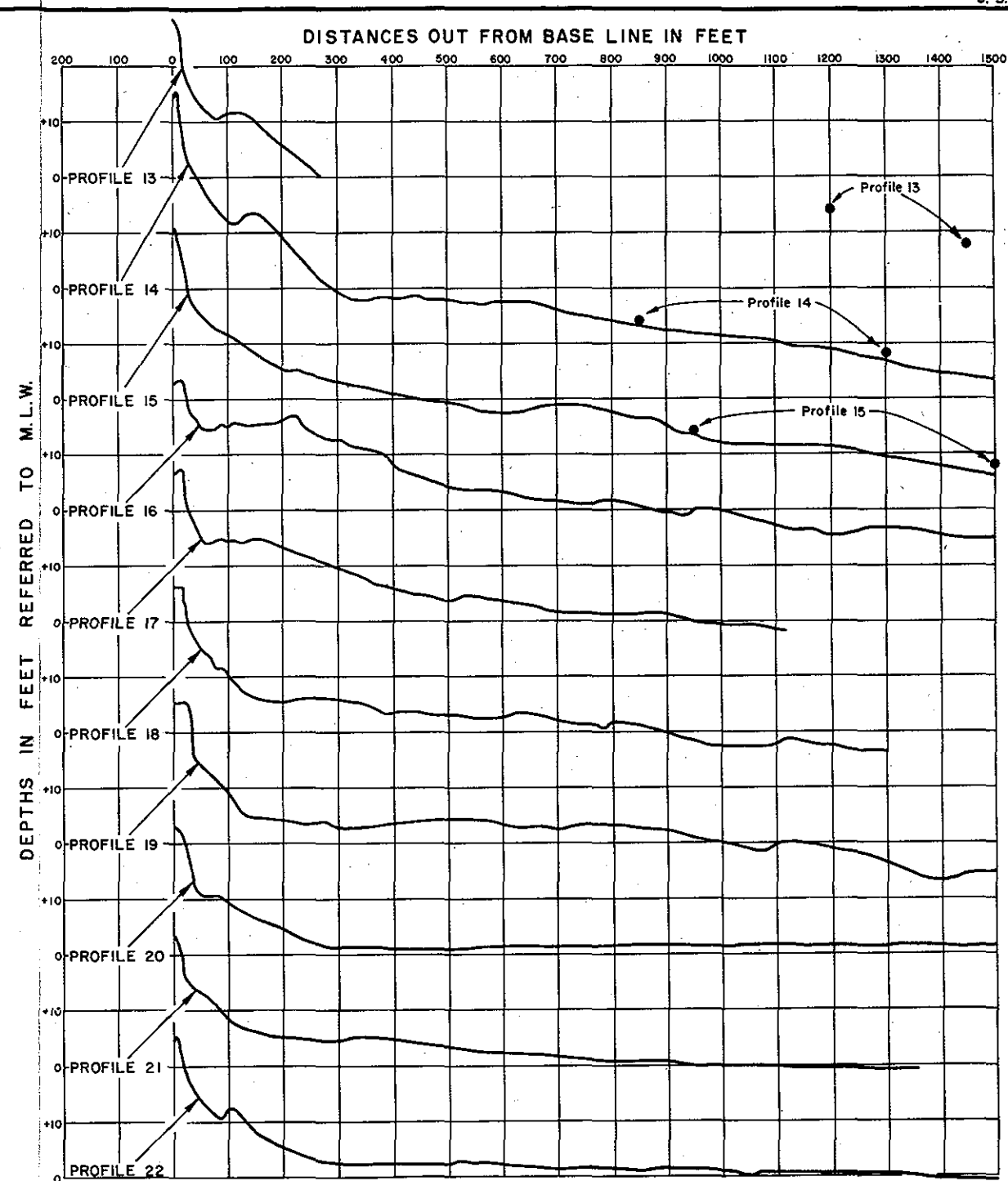












LEGEND

BEACH EROSION CONTROL STUDY OF
CAPE COD CANAL - PROVINCETOWN, MASS.

COMPARATIVE PROFILES

IN 2 SHEETS SCALE IN FEET SHEET 1

100' 200' 300' 400' 500'

NEW ENGLAND DIVISION, WALTHAM, MASS.

APPROVED: *[Signature]* APPROVED: *[Signature]*

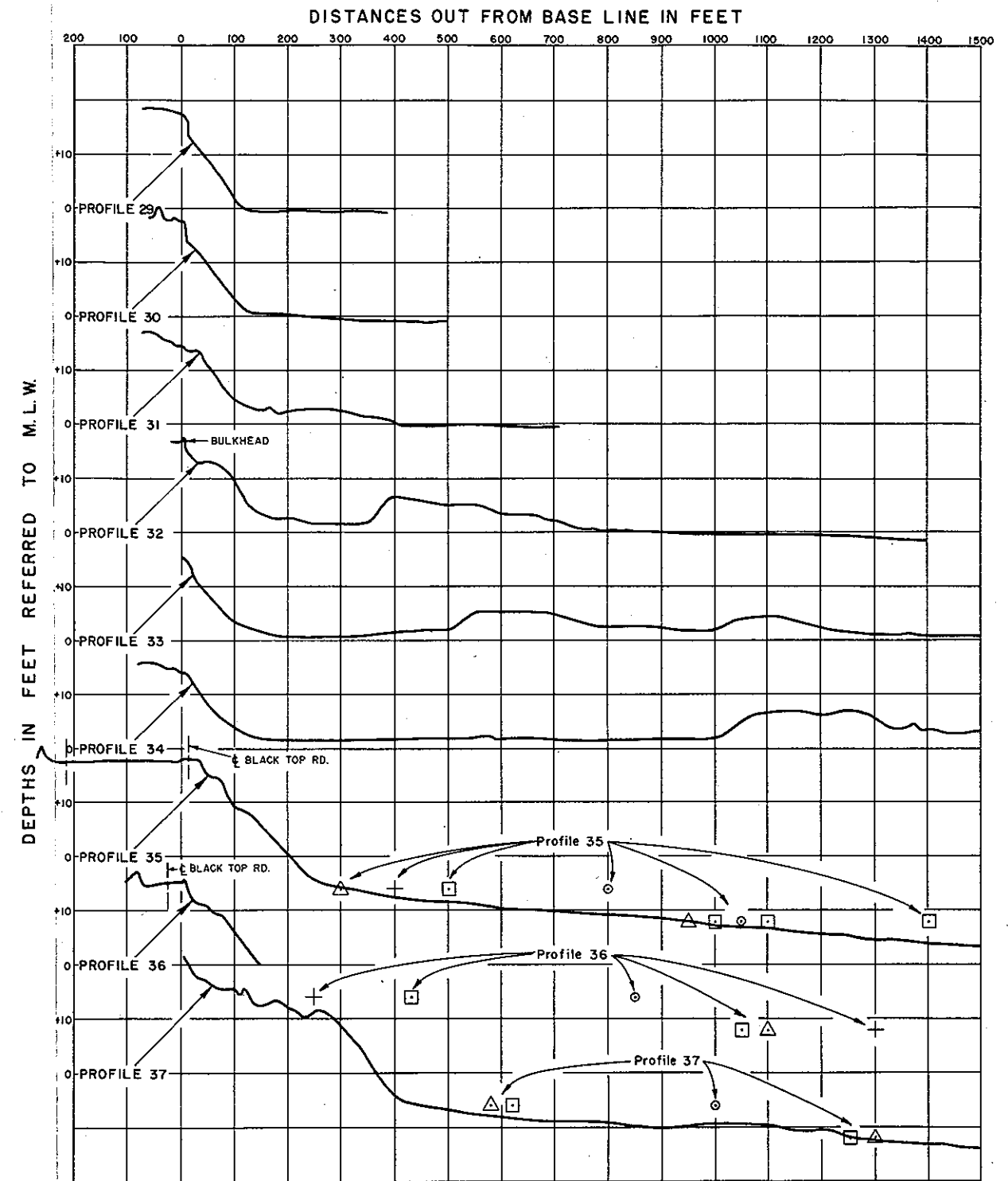
CHIEF ENGINEERING DIVISION CHIEF, C. E. DEPUTY DIVISION ENGINEER

SUBMITTED: TRANSMITTED WITH REPORT DATED OCT. 2, 1959

CERT. PLANNING AND DESIGN BRANCH OR BYALD

CERT. RIVER AND HARBOR SECT. TR BYALD

FILE NO. B. E. M. 15



LEGEND

1833-35—☒
 1899-90—☐

1909—+

1933—

IN 2 SHEETS SCALE IN FEET SHEET 2

Var. 10 0 10 20 30 40 50

NEW ENGLAND DIVISION, WALTHAM, MASS.

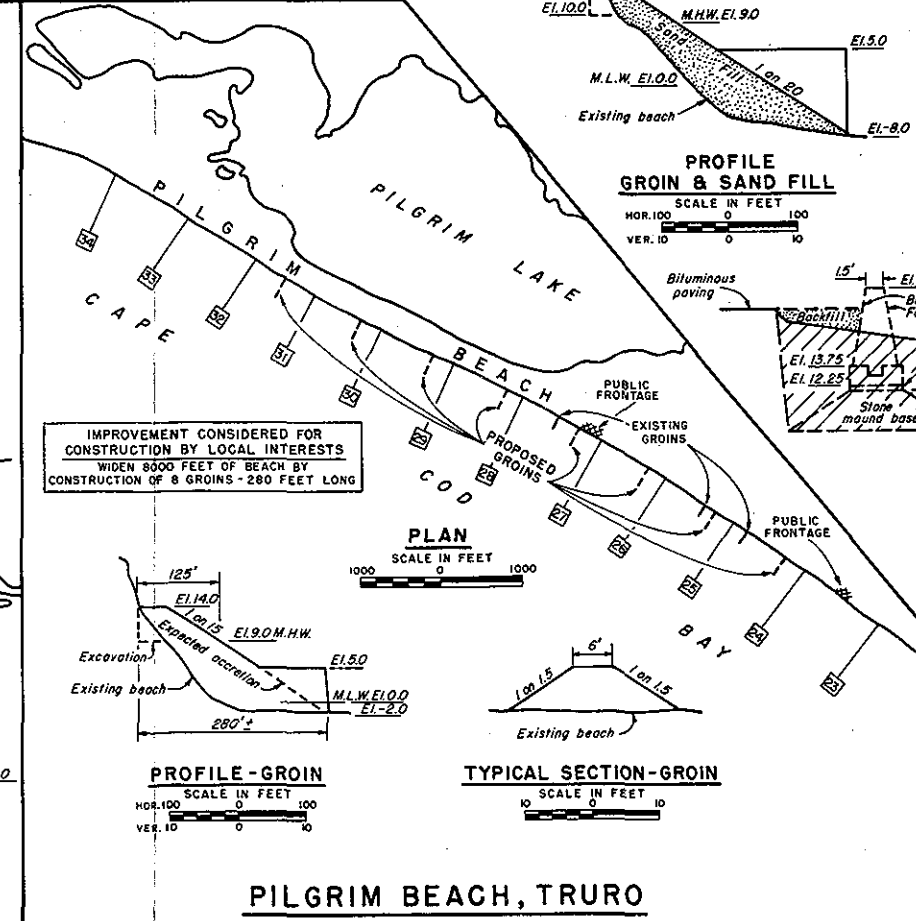
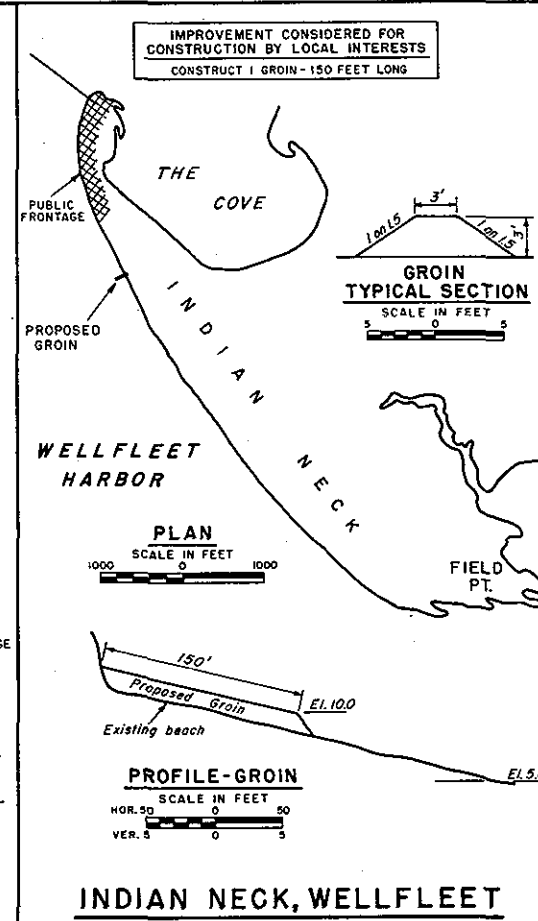
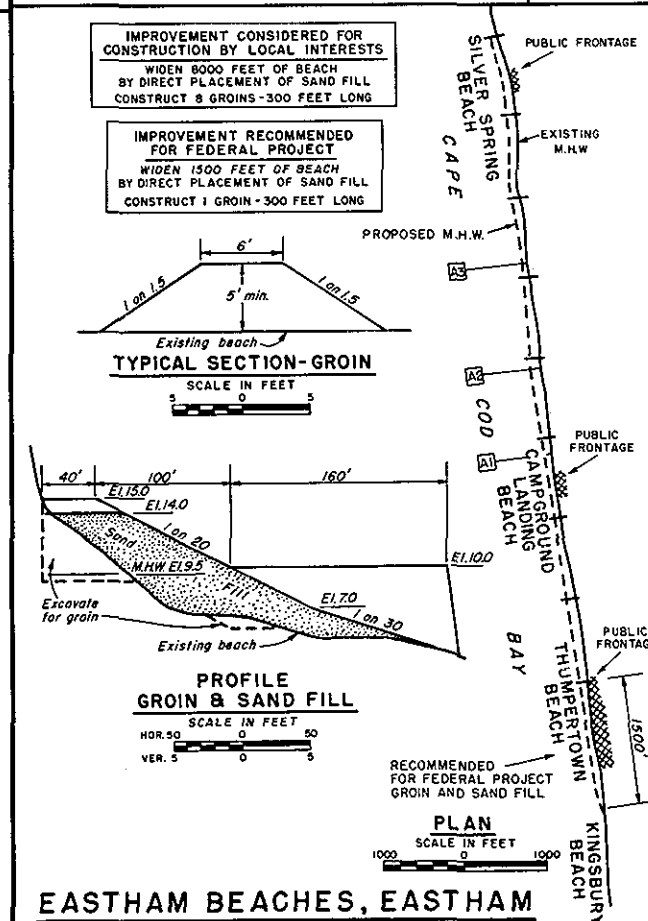
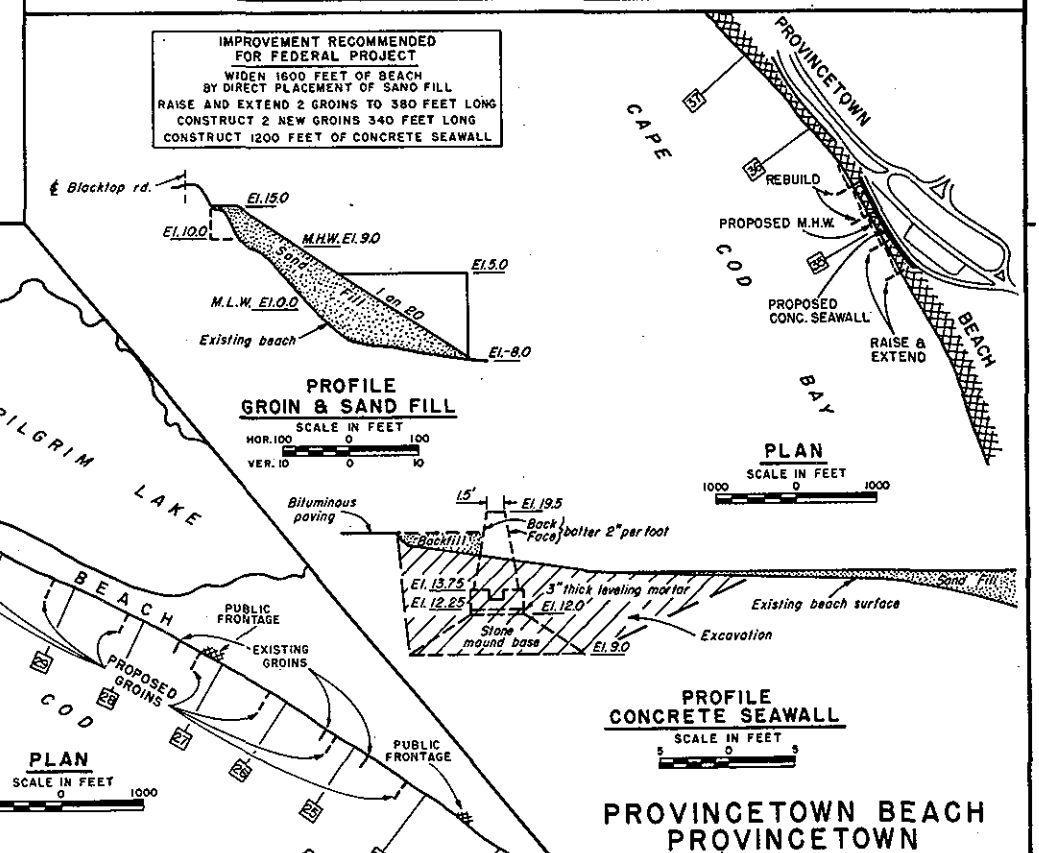
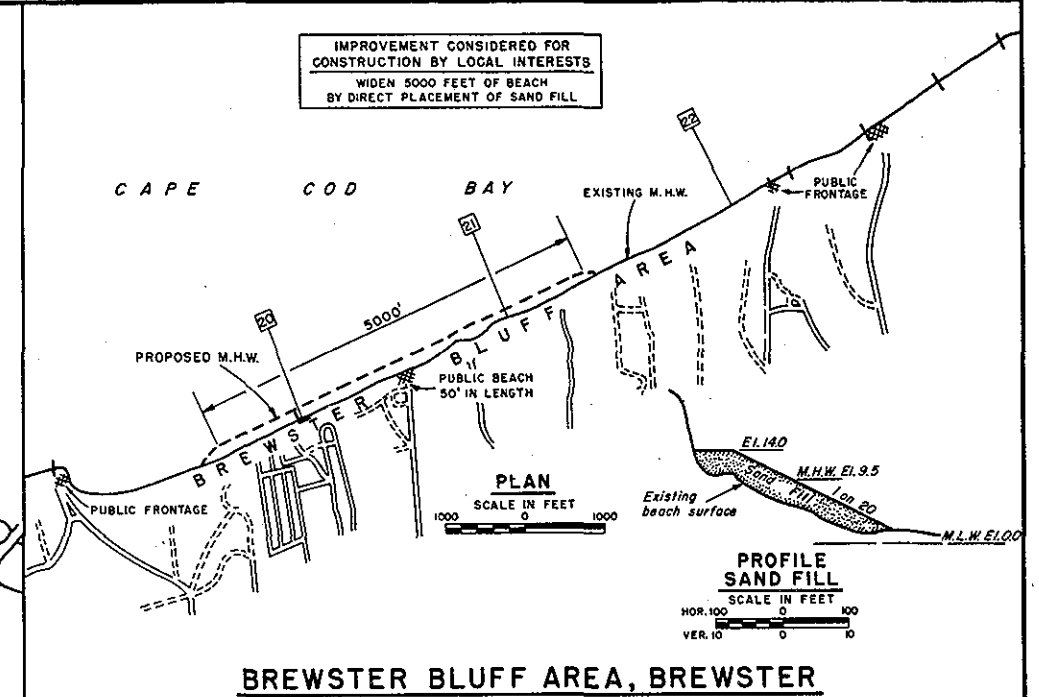
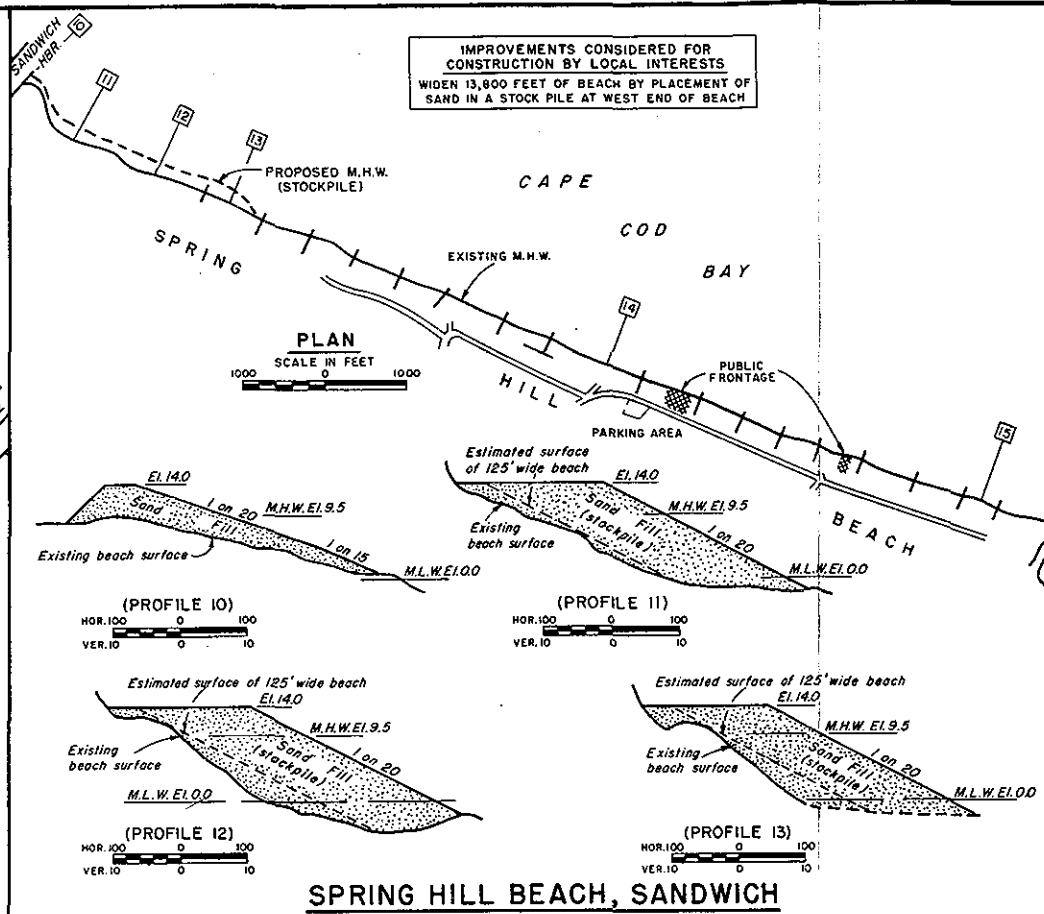
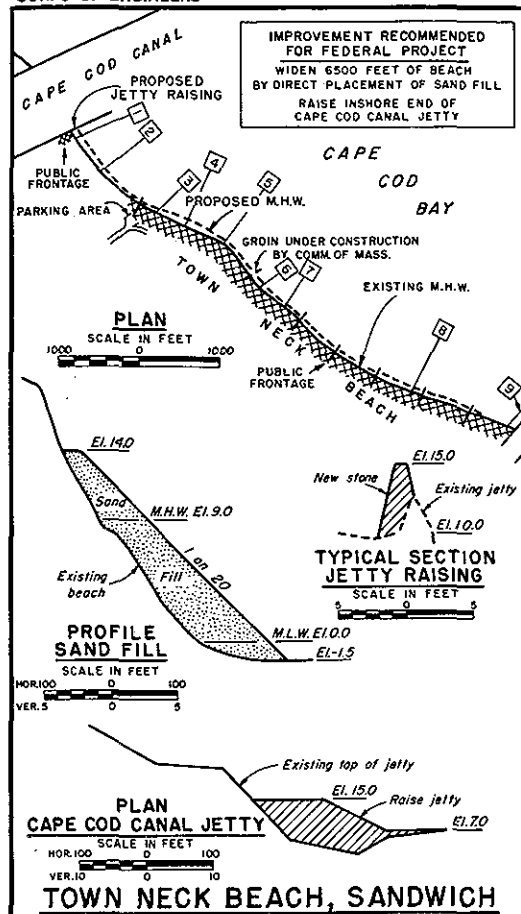
CHIEF, ENGINEERING DIVISION

RECEIVED: *[Signature]* COL. C.E. DEPUTY DIVISION ENGINEER
TRANSMITTED WITH REPORT

CHIEF, PLANNING AND REPORTS BRANCH
A. W. [Signature]
CR. BYALD
DATED OCT. 2, 1959

CHIEF, RIVER AND HARBOR SECT.	TR BYALD	FILE NO. B.E.M. 15
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PROJECT ENGINEER	CH. BY:
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BEACH EROSION CONTROL STUDY OF
CAPE COD CANAL - PROVINCETOWN, MASS.

PLANS OF IMPROVEMENT

I N | SHEET

SCALES AS SHOWN

NEW ENGLAND DIVISION, WALTHAM, MASS.

APPROVED: [Signature] APPROVED: [Signature]
[Signature] COL. C.E. DEPUTY DIVISION ENGINEER

SUBMITTED BY: [Signature] TRANSMITTED WITH REPORT
DATE OCT. 2, 1959

CITY ENGINEERING DIVISION

SECT. CHIEF AND DISTRICTS ENGINEER

CHIEF CLERK AND RECORDS MGR.

TRIAL BALD

CH. ENG.

FILE NO. B.E.M. 16